Virtual Event
August 16-20, 2021

WFCC
WORLD FUEL CELL CONFERENCE

Please visit our website and social media for more information:

Website: https://www.iahe-fcd.org/wfcc2021

Conference Platform: https://wfcc2021.us2.pathable.com

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Twitter: https://twitter.com/iahe_fcd?lang=en

2021 World Fuel Cell Conference

August 16-20, 2021

Virtual Conference

Conference Program

International Association for Hydrogen Energy

IAHE Fuel Cell Division

CHFCA Clean. Efficient. Energy.

UNIVERSITY OF WATERLOO

WATERLOO INSTITUTE FOR nanotechnology

Acknowledgement

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2021 World Fuel Cell Conference (WFCC2021)

Detailed Agenda

Sunday, August 15, 2021

Plan	(All EDT Time, UTC-4)
Sunday	**15 August 2021**
Pre-conference student events	
8:30 am - 10:30 am	**3MT competition (for graduate students)** **Please submit your 3-minute presentation to sunyingts@163.com (Ms. Ying Sun) by August 5.** **More information: https://www.iahe-fcd.org/wfcc-2021-virtual-3mt-contest** 1st Prize Sponsor: **Anton Paar**

Monday, August 16, 2021

Plan	(All EDT Time)
Monday	**16 August 2021**
8:00 am - 8:50 am	**Opening Session**
8:50 am - 9:40 am	**Dr. Craig Gittleman (General Motors)** Materials Research and Development Focus Areas for Low Cost Automotive Proton-Exchange Membrane Fuel Cells (will be recorded but available until Sept 3) Session Chair: Andy Chen, FTXT Energy Technology Co., Ltd. (Plenary session sponsored by Toray Research Centre, Inc.)

Session 1: Fuel cell catalysts 1 **Session Chair: Pierre Bénard, University of Quebec Trois Rivieres**	
9:45 am - 10:20 am	**Invited**: WFCC2021-202 Sonocatalysis – A “sound” process for producing hydrogen and catalytic materials for fuel cells and electrolyzers Bruno G. Pollet Norwegian University of Science and Technology
10:20 am - 10:40 am	WFCC2021-003 Electronic structure studies of graphene and graphene based functional materials by soft X-ray absorption spectroscopy and spectromicroscopy at Canadian Light Source Jigang Zhou Jigang.Zhou@lightsource.ca Canadian Light Source
10:40 am - 11:00 am	WFCC2021-053 Synthesis and transmission electron microscopy (TEM) characterization of platinum on carbon nanoparticles selectively coated with titanium nitride (TIN) Andres Godoy richard.ortiz_godoy@uconn.edu University of Connecticut
11:00 am - 11:20 am	WFCC2021-055 Effect of catalyst ink formulation and dispersion process on catalyst layer microstructure and further on performance and durability of PEMFCs Huiyuan Liu h577liu@uwaterloo.ca University of Waterloo

Session 2: Computation in fuel cells 1 **Session Chair: Kui Jiao, Tianjin University**	
9:45 am - 10:20 am	**Invited**: WFCC2021-212 Pore-Scale Modeling of Electrode Processes Jeff Gostick University of Waterloo
10:20 am - 10:40 am	WFCC2021-101 Interpretation of the low-frequency inductive behavior in impedance spectra of PEFCs Wenbo Shi swb17@mails.tsinghua.edu.cn Tsinghua University
10:40 am - 11:00 am	WFCC2021-115 Modelling the Ionomer Morphology in Highly Porous Carbon Supports Anne-Christine Scherzer anne-christine.scherzer@ise.fraunhofer.de Fraunhofer Institute for Solar Energy Systems
11:00 am - 11:20 am	WFCC2021-113 Neural network modelling of Toyota Mirai proton exchange membrane fuel cells using principal component analysis Chris Shum chris.shum@uwaterloo.ca University of Waterloo

<table>
<tr><th colspan="2">Session 3: PEM fuel cell 1
Session Chair: Nada Zamel, Fraunhofer Institute ISE</th></tr>
<tr><td>9:45 am - 10:20 am</td><td>Invited: WFCC2021-207 PEM technology for water electrolysis and electrochemical hydrogen compression
Dmitri Bessarabov HySA Center</td></tr>
<tr><td>10:20 am - 10:40 am</td><td>WFCC2021-023 Power performance and degradation of gold alloyed platinum-silver nanorod array electrodes in H2/air PEMFCs
Shangfeng Du s.du@bham.ac.uk University of Birmingham</td></tr>
<tr><td>10:40 am - 11:00 am</td><td>WFCC2021-071 On the unexpected voltage loss in polymer electrolyte fuel cells at ultra low-platinum loading - a water balance model
Yufan Zhang yuf_zhang@fz-juelich.de Juelich Research Center</td></tr>
<tr><td>11:00 am - 11:20 am</td><td>WFCC2021-121 Numerical investigation of impact of orientation on water transport in PEMFC serpentine flow channels
Ahmet Kilavuz kilavuz.ahmet@gmail.com Abdullah Gül University</td></tr>
</table>

11:20 am - 12:20 pm	**Poster session**

7:00 pm - 7:50 pm	**Dr. Jun Liu (Pacific Northwest National Laboratory)** Electrons or Hydrogen – The Choices for Future Energy Storage Session Chair: Shuhui Sun, INRS

<table>
<tr><th colspan="2">Session 4: Fuel cell catalysts 2
Session Chair: Bruno Pollet, University of Quebec Trois Rivieres</th></tr>
<tr><td>7:55 pm - 8:30 pm</td><td>Invited: WFCC2021-203 Impact of Ionomer Ratio, Type and Design on Fuel Cell Performance and Durability under Different Operational Conditions
Samaneh Shahgaldi University of Quebec à Trois-Rivières</td></tr>
<tr><td>8:30 pm - 8:50 pm</td><td>WFCC2021-075 Performance and durability study of PEM fuel cells made of catalysts with non-spherical platinum nanoparticles of different sizes
Xiaoyu Tan x2tan@uwaterloo.ca University of Waterloo</td></tr>
<tr><td>8:50 pm - 9:00 pm</td><td>Break</td></tr>
<tr><td>9:00 pm - 9:20 pm</td><td>WFCC2021-095 Interface characteristics and ionomer coverage of electrospun catalyst layers for polymer electrolyte fuel cells
Han Liu hliu0610@163.com Beijing University of Chemical Technology</td></tr>
<tr><td>9:20 pm - 9:40 pm</td><td>WFCC2021-105 Multi-scale study on bifunctional M–N–C cathode catalyst layers for hydrogen fuel cell
Weikang Zhu lovsunny77@tju.edu.cn Tianjin University</td></tr>
</table>

<table>
<tr><th colspan="2">Session 5: Computation in fuel cells 2
Session Chair: Jasna Jankovic, University of Connecticut</th></tr>
<tr><td>7:55 pm - 8:30 pm</td><td>Invited: WFCC2021-211 Pore-scale and Multiscale Numerical Study of Physicochemical Processes in PEM Fuel Cell
Li Chen Xi’an Jiaotong University</td></tr>
<tr><td>8:30 pm - 8:50 pm</td><td>WFCC2021-009 Introduction and validation of a “3D+1D” Proton Exchange Membrane fuel cell model
Biao Xie xiebiao@tju.edu.cn Tianjin University</td></tr>
<tr><td>8:50 pm - 9:00 pm</td><td>Break</td></tr>
</table>

9:00 pm - 9:20 pm	WFCC2021-085 Three-dimensional Modeling and Analysis of PEMFCs with Low Pt Loading Regarding Initial Performance and Performance after Pt Degradation Yubai Li liyubai2021@126.com Dalian University of Technolgy
9:20 pm - 9:40 pm	WFCC2021-089 Nanofiber unit model for electrospun catalyst layer Dechun SI sdc16@mails.tsinghua.edu.cn Tsinghua University
9:40 pm - 10:00 pm	

Session 6: PEM fuel cell 2 **Session Chair: Jeff Gostick, University of Waterloo**	
7:55 pm - 8:30 pm	**Invited**: WFCC2021-214 Fuel Cell Durability Improvements Guided by 4D In-situ X-ray Visualization Erik Kjeang Simon Fraser University
8:30 pm - 8:50 pm	WFCC2021-087 Proton conduction mechanism of ionomer nanofiber: non-monotonic size effect Shangshang Wang wang-ss13@tsinghua.org.cn Tsinghua University
8:50 pm - 9:00 pm	Break
9:00 pm - 9:20 pm	WFCC2021-045 Comprehensive degradation analysis of the PEMFCs operated under start/stop cycle tests by morphological and chemical structure analysis Tsuyoshi Akiyama tsuyoshi_akiyama@trc.toray.co.jp Toray research Center, Inc.
9:20 pm - 9:40 pm	WFCC2021-043 understanding of the effect of pore-forming on oxygen transport behavior in ultra-low Pt PEMFCs XiaojingCheng chengxj0123@sjtu.edu.cn Shanghai Jiao Tong University
9:40 pm - 10:00 pm	WFCC2021-037 Molecular dynamics simulation on the conductive and mechanical performance of advanced aromatic electrolytes in PEMFC Zhiguo Qu zgqu@mail.xjtu.edu.cn Xi’an Jiaotong University

Tuesday, August 17, 2021

Plan	(All EDT Time)
Tuesday	**17 August 2021**
8:00 am - 9:45 am	**Dr. Sunita Satyapal (United States Department of Energy)** U.S. Department of Energy's Hydrogen and Fuel Cell Perspectives Session Chair: Tobias Brunner, Hynergy GmbH
	Dr. Tobias Brunner (HYNERGY GmbH) Hydrogen on the Way to Competitiveness – A Hydrogen Cost and Decarbonization Perspective Session Chair: Jianbo Zhang, Tsinghua University
	Panel Discussion Session (Moderator: Dr. Tobias Brunner) **Topic: Hydrogen Fuel Cell Technology and Market Trends** Panelists: • Dr. Gouyan Hou, CTO Weichai-Ballard Hy-Energy Technologies Com., Ltd.; Technical Director of Ballard China • Dr. Sunita Satyapal, Director of EERE's Hydrogen and Fuel Cell Technologies Office, the US • Jorgo Chatzimarkakis, CEO of Hydrogen Europe • Ju Wang, Deputy Secretary General of Chinese SAE, China • Katsuhiko Hirose, CEO & Chief consultant in HyWealth and visiting professor in Kyushu University, Japan
9:50 am - 10:50 am	**Networking (Breakout rooms)**
11:00 am - 11:50 pm	**Dr. David Hart (E4tech)** How fuel cells can help both recovery and climate in a post-covid world Session Chair: Ibrahim Dincer, Ontario Tech University
Noon break	
2:00 pm - 4:00 pm	**Dr. Andrei V. Tchouvelev** Chair, ISO/TC 197 Hydrogen Technologies; President, IAHE Hydrogen Safety Division; President & CEO, A.V. Tchouvelev & Associates **Hydrogen Safety Best Practices** Session Chair: Jian Zhao, University of Waterloo
4:00 pm – 5:00 pm	**Sponsor exhibition**
Afternoon break	
7:00 pm - 7:50 pm	**Dr. Piotr Zelenay (Los Alamos National Lab)** Durability of PGM-Free ORR Catalysts: Recent Progress Session Chair: Xueliang (Andy) Sun, University of Western Ontario

Session 7: Fuel cell catalysts 3 **Session Chair: Samaneh Shahgaldi, University of Quebec Trois Rivieres**	
7:55 pm - 8:30 pm	**Invited**: WFCC2021-204 Low-Pt and Pt-free Catalysts for Hydrogen Fuel Cells Shuhui Sun Institut National de la Recherche Scientifique
8:30 pm - 8:50 pm	WFCC2021-099 Hybrid hydrophilic–hydrophobic electrospun micro-porous layer for proton electrolyte fuel cells Xin Li llixinhit@163.com Beijing University of Chemical Technology

8:50 pm - 9:00 pm	Break
9:00 pm - 9:20 pm	WFCC2021-025 Effect of CNTs support in Cl of PEMFC on the structure of ionomer ultra-thin film Yue Wan wanyue2018@sjtu.edu.cn Shanghai Jiao Tong University
9:20 pm - 9:40 pm	WFCC2021-065 Highly Dispersed PtCo Nanoparticles on Self-Assembled Hierarchically Ordered Mesoporous Carbon Support for Polymer Electrolyte Membrane Fuel Cells Yi Yang yangyi@ms.giec.ac.cn Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences

<table>
<tr><th colspan="2">Session 8: Computation in fuel cells 3
Session Chair: Yun Wang, University of California Irvine</th></tr>
<tr><td>7:55 pm - 8:30 pm</td><td>Invited: WFCC2021-213 Artificial intelligence assisted design of next-generation high-power-density proton exchange membrane fuel cell
Kui Jiao Tianjin University</td></tr>
<tr><td>8:30 pm - 8:50 pm</td><td>WFCC2021-093 Effect of gas transport resistance of ionomer covering on platinum surface on catalyst layer performance
Yiming Zhang zhang-ym20@mails.tsinghua.edu.cn Tsinghua University</td></tr>
<tr><td>8:50 pm - 9:00 pm</td><td>Break</td></tr>
<tr><td>9:00 pm - 9:20 pm</td><td>WFCC2021-007 Preheating hydrogen using vortex tubes for improved cold start of hydrogen fuel cell electric vehicles
Junior Lagrandeur Junior.Lagrandeur@USherbrooke.ca Université de Sherbrooke</td></tr>
<tr><td>9:20 pm - 9:40 pm</td><td>WFCC2021-077 Mechanistic modeling and optimization of alternate hydrogen pump method of cold start of PEFC
Haosen Xu xhs19@mails.tsinghua.edu.cn Tsinghua University</td></tr>
</table>

<table>
<tr><th colspan="2">Session 9: PEM fuel cell 3
Session Chair: Zhiguo Qu, Xi’an Jiaotong University</th></tr>
<tr><td>7:55 pm - 8:30 pm</td><td>Invited: WFCC2021-215 Transient, multi-phase analysis of polymer electrolyte fuel cells: Insights from computational modeling at multiple scales and experiments
Marc Secanell University of Alberta</td></tr>
<tr><td>8:30 pm - 8:50 pm</td><td>WFCC2021-049 A novel approach in imaging and mapping of ionomer in the polymer electrolyte membrane fuel cell
Amir Peyman Soleymani ap.soleymani@uconn.edu University of Connecticut</td></tr>
<tr><td>8:50 pm - 9:00 pm</td><td>Break</td></tr>
<tr><td>9:00 pm - 9:20 pm</td><td>WFCC2021-057 Anode recirculation strategy optimization for proton exchange membrane fuel cell by segmented cell technology
Jinqiao Liang darren_liangjq@tju.edu.cn Tianjin University</td></tr>
<tr><td>9:20 pm - 9:40 pm</td><td>WFCC2021-015 Effects of flow channel obstacle settings on the performance of proton exchange membrane fuel cell
Qinwen Yang yangqw@hnu.edu.cn Hunan University</td></tr>
</table>

Wednesday, August 18, 2021

Plan	(All EDT Time)
Wednesday	**18 August 2021**
8:00 am - 8:50 am	**Dr. Detlef Stolten (Juelich Research Center)** Hydrogen Becoming a Commodity: A Requisite for Future Carbon-neutral Energy Systems Getting Reliable and Affordable Session Chair: Sushanta K Mitra, University of Waterloo
8:50 am - 9:40 am	**Dr. Ahmed Ghoniem (Massachusetts Institute of Technology)** Thermochemical Production of Green and Grey Hydrogen Session Chair: XiaoYu Wu, University of Waterloo

Session 10 (invited special) Membrane electrolyte materials 1 **Session Chair: Ken Shi** (National Research Council of Canada) **and Michael Guiver** (Tianjin University)	
9:45 am - 10:20 am	**Keynote:** WFCC2021-220 Molecular engineering of ion-conducting polymers for electrochemical energy conversion technologies Chulsung Bae Rensselaer Polytechnic Institute
10:20 am - 10:40 am	WFCC2021-143 Chain conformation-dependent ion conductivity of PEM: a molecular dynamics study Chenyang Zheng zhengchenyang@tju.edu.cn Tianjin University
10:40 am - 11:00 am	WFCC2021-147 Polymer electrolyte membrane with core-shell tin pyrophosphate proton conductor for fuel cells above 200°C Jin Zhang zhangjin1@buaa.edu.cn Beihang University
11:00 am - 11:20 am	WFCC2021-107 Tolerance of membrane with additive to iron contamination in PEM fuel cell Nana Zhao Nana.Zhao@nrc-cnrc.gc.ca National Research Council Canada
11:20 am - 11:40 am	WFCC2021-123 Understanding structure-transport relationship of ion conducting polymers Jessica Xiaoyan Luo jessica.luo.2008@gmail.com Ballard Power Systems
11:40 am - 12:00 pm	WFCC2021-109 Pemion®: fully hydrocarbon PEMFCs for high temperature exhibiting performance and durability Michael Adamski adamski@ionomr.com Ionomr Innovations, Inc.

Session 11: Fuel cell catalysts 4 **Session Chair: Lei Zhang, National Research Council of Canada**	
9:45 am - 10:20 am	**Invited:** WFCC2021-205 CO- and H_2S-Tolerant Electrocatalysts for Hydrogen Oxidation Reaction in Proton Exchange Membrane Fuel Cells Wei Yan Shanghai University
10:20 am - 10:40 am	WFCC2021-005 Morphology and mechanism of highly efficient NiFe layered double hydroxide for oxygen evolution reaction Wulyu Jiang j.wulv@fz-juelich.de Forschungszentrum Juelich
10:40 am - 11:00 am	WFCC2021-002 Platinum-Oxygen Interaction Evolution of Pt3Co Nanowires by Mo Doping Enabling Enhanced Oxygen Reduction Reaction Performance Xiaolei Wang xiaolei.wang@ualberta.ca University of Alberta

11:00 am - 11:20 am	WFCC2021-135 PEM fuel cells catalyst layer reconstruction and morphological deterioration under hygrothermal cycles Yixiang Zhang a4lamber@uwaterloo.ca University of Waterloo

<table>
<tr><td colspan="2">Session 12: Hydrogen production and utilization
Session Chair: Shangfeng Du, University of Birmingham</td></tr>
<tr><td>9:45 am - 10:20 am</td><td>Invited: WFCC2021-208 Pathways to highly efficient hydrogen production: manipulating transport and electrochemical reaction with ultralow catalyst loading
Feng-Yuan Zhang University of Tennessee</td></tr>
<tr><td>10:20 am - 10:40 am</td><td>WFCC2021-027 A comparative well-to-pump energy, environmental and economical (3E) assessment of methanol and hydrogen as alternative fuels for vehicles
Jiaxuan Li 20171002031t@cqu.edu.cn Chongqing University</td></tr>
<tr><td>10:40 am - 11:00 am</td><td>WFCC2021-129 An experimental assessment of performance, emission and combustion of DTSI high speed engine fueled with gasoline, CNG and hydrogen
Balu Shinde bjshinde2002@gmail.com Vellore Institute of Technology, Force Motors Ltd</td></tr>
<tr><td>11:00 am - 11:20 am</td><td>WFCC2021-125 Optimizing hybrid battery and hydrogen energy storage for a renewable microgrid
Michael Giovanniello magiovanniello@email.wm.edu University of Waterloo</td></tr>
<tr><td>11:20 am - 11:40 am</td><td>WFCC2021-017 Analysis of the purity of hydrogen at public hydrogen refuelling stations in Germany
Holger Janssen holger.janssen@dlr.de German Aerospace Center</td></tr>
<tr><td>11:40 am - 12:00 pm</td><td>WFCC2021-133 Electric taxiing with fuel cell hybrid power unit and its environmental impact at airports
Mustafa Keçeci mustafakececi@anadolu.edu.tr Eskişehir Technical University</td></tr>
</table>

7:00 pm - 7:50 pm	**Dr. Michael Guiver (Tianjin University, will not be recorded)** Innovations in Fuel Cell Membranes Session Chair: Chulsung Bae, Rensselaer Polytechnic Institute

<table>
<tr><td colspan="2">Session 13 (invited special): Membrane electrolyte materials 2
Session Chair: Yan Yin (Tianjin University) and Ken Shi (NRC)</td></tr>
<tr><td>7:55 pm - 8:30 pm</td><td>Keynote: WFCC2021-219 Fuel cell performances of sulfonated multiblock copolymer membranes
Jianhua Fang Shanghai Jiao Tong University</td></tr>
<tr><td>8:30 pm - 8:50 pm</td><td>WFCC2021-111 Improving ion conductivity in anion exchange membranes by utilizing polymers of intrinsic microporosity (PIMS)
Yan Yin yanyin@tju.edu.cn Tianjin University</td></tr>
<tr><td>8:50 pm - 9:00 pm</td><td>Break</td></tr>
<tr><td>9:00 pm - 9:20 pm</td><td>WFCC2021-141 Mechanistic and experimental study of the formation of biofunctionalized nanofiber hybrid membrane with enhanced proton conductivity</td></tr>
</table>

	Guodong Zhao zhaoguodong1314@126.com Tiangong University
9:20 pm - 9:40 pm	WFCC2021-145 Proton conducting covalent organic framework membranes for hydrogen fuel cell Hong Wu wuhong@tju.edu.cn Tianjin University
9:40 pm - 10:00 pm	WFCC2021-149 High density sulfonated carbon nano-onions as an efficient proton conductor for synthesis of nanocomposite membranes with enhanced water retention and durability Lili Liu liulilintu@126.com Nanjing University of Science and Technology

Session 14: Fuel cell catalysts 5
Session Chair: Wei Yan, Shanghai University

7:55 pm - 8:30 pm	**Invited:** WFCC2021-206 Modulation strategy of active sites in carbon-based electrocatalysts for oxygen reduction reaction Shiming Zhang Shanghai University
8:30 pm - 8:50 pm	WFCC2021-063 Long-range ordered Pt-based nanocatalysts for oxygen reduction reaction Zhi-da Wang wangzd@ms.giec.ac.cn Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences
8:50 pm - 9:00 pm	Break
9:00 pm - 9:20 pm	WFCC2021-127 Understanding the origin of the large onset overpotential for oxygen reduction on Pt(111) in acidic medium by solvation and reaction dynamics Zhi-Feng Liu zfliu@cuhk.edu.hk Department of Chemistry, Chinese University of Hong Kong
9:20 pm - 9:40 pm	WFCC2021-013 Impacts of porous carbon support microstructure on O_2 transport in the catalyst layer of PEM fuel cells Linhao Fan lhfan@tju.edu.cn State Key Laboratory of Engines, Tianjin University

Session 15: PEM fuel cell 4
Session Chair: Feng-Yuan Zhang, University of Tennessee

7:55 pm - 8:30 pm	**Invited**: WFCC2021-216 High performance sealing technology for stack assembly in proton exchange membrane fuel cell (PEMFC) Zixi Wang Tsinghua University
8:30 pm - 8:50 pm	WFCC2021-019 Development of a tubular PEM fuel cell Sara Pedram sara.pedram@uconn.edu University of Connecticut
8:50 pm - 9:00 pm	Break
9:00 pm - 9:20 pm	WFCC2021-119 Experimental study on the effect of purging conditions on PEMFC cold start performance Yue Fan 869947036@qq.com Tianjin University
9:20 pm - 9:40 pm	WFCC2021-061 Effects of thermal conductivity of electrodes on the performance of proton exchange membrane fuel cells Chaoling Han chrrey6688@qq.com Southeast University
9:40 pm - 10:00 pm	WFCC2021-131 DRE MOTORS - adoption of hydrogen technology in India Anurag Reddy business@dremotors.com DRE Motors

Thursday, August 19, 2021

Plan	(All EDT Time)
Thursday	**19 August 2021**
8:00 am - 8:50 am	**Panel Discussion Session (Moderator: Dr. Jianbo Zhang, Tsinghua University)** **Topic: Hydrogen and Fuel Cell Roadmap and R&DDD Around the World** Panelist: • Dr. Tobias Brunner, HYNERGY GmbH, Germany • Prof. Ibrahim Dincer, Ontario Tech University, Canada • Prof. Mingao Ouyang, Tsinghua University, China • Dr. Yu Morimoto, Former Research Leader of Toyota Research Center, Japan
8:50 am - 9:40 am	**Dr. ZhongWei Chen (University of Waterloo)** Advanced Platinum and Non-Platinum Catalysts for PEM Fuel Cells Session Chair: Dmitri Bessarabov, HySa Center at NWU

Session 16: Bipolar plate **Session Chair: Erik Kjeang, Simon Fraser University**	
9:45 am - 10:20 am	**Invited**: WFCC2021-201 Manufacturing of thin metallic bipolar plate for PEM fuel cells: development of forming and coating processes Linfa Peng, Shanghai Jiao Tong University
10:20 am - 10:40 am	WFCC2021-021 The Effect of Ion Clean, Deposition Power and Au Thickness on the Corrosion Resistance, Conductivity and Throughput Production Rates of Nano-Multilayer Ti/Au Coated SS316 Bipolar Plate for PEFCs KUN ZHANG k.zhang.2@bham.ac.uk University of Birmingham
10:40 am - 11:00 am	WFCC2021-041 Additive Manufacturing for Bipolar Plates in Proton Exchange Membrane Fuel Cells Aubrey Tang aubrey.tang@uconn.edu University of Connecticut
11:00 am - 11:20 am	WFCC2021-035 PVD coated aluminium bipolar plates for use in lightweight Polymer Electrolyte fuel cell stacks Liam Cooper ltc733@student.bham.ac.uk University of Birmingham

Session 17: PEM fuel cell 5 **Session Chair: Asmae Mokrini, National Research Council Canada**	
9:45 am - 10:20 am	Invited: WFCC2021-209 Novel concepts for membrane electrode assemblies in fuel cells and water electrolysers Simon Thiele Jülich Research Center and Friedrich-Alexander-Universität Erlangen-Nürnberg
10:20 am - 10:55 am	Invited: WFCC2021-210 Catalyst coated membranes – their structure, their performance and their durability Nada Zamel Fraunhofer Institute for Solar Energy Systems
10:55 am - 11:15 am	WFCC2021-031 Comparison of PEMFCs Based on Pt/C and Pt Nanowire Cathodes by Orthogonal Design Experiments Yichang Yan yxy953@student.bham.ac.uk University of Birmingham

Session 18: Other fuel cells **Session Chair: Li Chen, Xi'an Jiaotong University**

10:00 am - 10:20 am	WFCC2021-029 Effect of flow configuration on gas bubble distribution and cell performance for a microfluidic fuel cell with flow-through porous electrodes Qiao Lan 1530877109@qq.com Chongqing University
10:20 am - 10:40 am	WFCC2021-039 Controlled Growth of Pd catalysts on Gas Diffusion Layer for Direct Formic Acid Fuel Cells YANG Liyxl1157@student.bham.ac.uk University of Birmingham
10:40 am - 11:00 am	WFCC2021-011 Modification of carbon black as fuel to improve the performance of DCFC (direct carbon fuel cell) Quan Zhuang quan.zhuang@canada.ca CanmetENRGY, NRCan

11:30 am - 12:20 pm	**Dr. Laurent Antoni (CEA Liten)** High temperature electrolysis and alternative fuel feeding strategy and architecture of PEM Fuel Cell Stack to improve performance and stability while reducing costs of hydrogen production and usage Session Chair: Erik Kjeang, Simon Fraser University
Day break	
7:00 pm - 7:50 pm	**Dr. Xiao-Zi Yuan (National Research Council Canada)** Quality Control of PEM Fuel Cell Components Session Chair: Biao Zhou, University of Windsor

Session 19: PEM fuel cell 6
Session Chair: Xiao-Zi (Riny) Yuan, National Research Council of Canada

7:55 pm - 8:30 pm	**Invited**: WFCC2021-217 R&D strategies for low-cost high temperature polymer electrolyte membrane fuel cell technology Yan Xiang Beihang University
8:30 pm - 8:50 pm	WFCC2021-047 Liquid water transport behaviors at different air inlet flow rates in a PEMFC cathode with a biomimetic flow field Biao Zhou bzhou@uwindsor.ca University of Windsor
8:50 pm - 9:00 pm	Break
9:00 pm - 9:20 pm	WFCC2021-117 Superhydrophobic fluorinated carbons for the micro-porous layer of polymer electrolyte fuel cells Enes Muhammet CAN enesmuhammetcan@gmail.com Kyushu University
9:20 pm - 9:40 pm	WFCC2021-059 Liquid water transport behavior of electrospun gas diffusion layers with fine-tuned pore size gradients Zhiguo Qu zgqu@mail.xjtu.edu.cn Xi'an Jiaotong University

Session 20: 3MT awardee sessions

7:55 pm - 9:30 pm	TBD
Night break	

Friday, August 20, 2021

Plan	(All EDT Time)
Friday	**20 August 2021**
8:00 am - 8:50 am	**Dr. Asmae Mokrini (National Research Council Canada)** Novel Manufacturing Opportunities for PEM Cost Reduction and Durability Improvement Session Chair: Eric Croiset, University of Waterloo
8:50 am - 9:40 am	**Dr. Xueliang Andy Sun (Western University)** Single Atom Electrocatalysts for PEM Fuel Cells: Opportunity, Challenge and Progress Session Chair: Zhongwei Chen, University of Waterloo
9:50 am - 10:50 am	**Panel Discussion Session (Moderator: Dr. Jean St-Pierre, University of Hawaii)** **Topic: The circular economy and the fuel cell/hydrogen industry** Panelist: • Dimitrios Papageorgopoulos, United States Department of Energy • Javier Dufour, IMDEA Energy Institute, Madrid • Jason Cox, Johnson Matthey, London
11:00 am - 12:30 pm	**Panel Discussion Session (Moderator: Dr. Marc Secanell, University of Alberta)** **Topic: Computational Tools for Polymer Electrolyte Fuel Cell Analysis and Design** Panelists: • S. Beale, Forschungszentrum Jülich, Germany • M. Eikerling, RWTH Aachen University and Forschungszentrum Jülich (IEK-13), Germany • J. Gostick, University of Waterloo, Canada • A. Weber, Lawrence Berkeley National Laboratory, US
Day break	

7:00 pm - 7:50 pm	**Mr. Shigeki Hasegawa (Toyota Motor Corporation)** Physical Modeling of Fuel Cell System and Application to Product System and Control Development Session Chair: Xianguo Li, University of Waterloo
7:55 pm - 8:30 pm	**Award ceremony and closing remarks**

Abstracts of Plenary Sessions

Biographies of Plenary Speakers

Name	Laurent Antoni	
Affiliation	CEA Liten, France; President, Hydrogen Europe Research	
Invited Plenary Lecture		
Presentation Title	High temperature electrolysis and alternative fuel feeding strategy and architecture of PEM Fuel Cell Stack to improve performance and stability while reducing costs of hydrogen production and usage	
Abstract (Approximately 200 words)	The potential of hydrogen is being recognized worldwide, with strategies, plans and investments by government and industry ramping up in many countries, in particular in Europe. The year 2020 has seen the emergence of hydrogen strategies in many European countries and for EU as a whole. The European Hydrogen Strategy sets out an ambitious vision of how Europe can turn clean H_2 into a viable solution to decarbonize different sectors over time. Over the past decades, owing to a continuous European support to research, development and innovation, hydrogen technologies have transitioned from highly specialized applications to commercially available products, in particular owing to strong public-private partnerships. These private-public partnerships have been ensuring coordinated activities based on a common understanding and vision of the European industry represented by Hydrogen Europe, the European research represented by Hydrogen Europe Research and the European Commission. After presenting the main European objectives for the next decade, a focus will be given on the remaining research challenges with an illustration of CEA's contribution with its activities on high temperature electrolysis, alternative fuel feeding strategy and architecture of PEM Fuel Cell Stack to improve performance and stability while reducing costs of hydrogen production and usage.	
Biographical Sketch (Approximately 200 words)	Dr. Laurent Antoni is Public Affairs manager for hydrogen technologies at CEA Liten. He gained his Engineering degree in 1992 and started his career as a senior scientist on material sciences at Mittal Group (Arcelor). In 2003, he joined the CEA, a Public Research Institute with a mandate to develop metallic bipolar plates for fuel cells. In 2005, he was nominated Head of the Hydrogen and Fuel Cell Laboratory at the CEA and managed a team to intensify R&D activity on hydrogen and fuel cells. In 2013, he was nominated Division Manager with 180 permanent staff to develop battery and fuel cell technologies for transportations through an integrated approach from materials up to demonstrators using technological platforms to enhance technological transfer to industry. Laurent Antoni is since 2016 President of Hydrogen Europe Research, the European research association on hydrogen and fuel cells gathering more than 90 universities and research institutes, member of the Governing Board of the European Fuel Cells and Hydrogen Joint Undertaking (FCH 2 JU). He is also President of the Technical Committee of Fuel Cells at the International Electrotechnical Commission (IEC/TC105) and a national representative in different working groups of international organizations (IEA Advanced Fuel Cells, IEA Hydrogen TCP, International Partnership for Hydrogen and fuels cells in the Economy - IPHE). He contributes to several peer reviewed books and publications.	

Name	Dr. Tobias Christoph Brunner	
Affiliation	Managing Director, Hynergy GmbH, Germany and Cryomotive GmbH, Germany, and former Vice President, Hydrogen Business Great Wall Motor China	
Invited Plenary Lecture		
Presentation Title	**Hydrogen on the Way to Competitiveness – A Hydrogen Cost and Decarbonization Perspective**	
Abstract (Approximately 200 words)	The Hydrogen Council, the world's largest CEO-backed organization to promote the establishment of a hydrogen economy during its CEO event on 20.01.2020 in Paris has published an industry-led study on the cost development of hydrogen technologies in multiple sectors including mobility, energy, industry and heating, which will see an update in 2020/21 The study revealed that the competitiveness of hydrogen technologies is closer than many expected and that investment to overcome the gap is moderate compared with investments in today's energy and fuel systems. Until 2030 nine mobility applications reach competitive cost to conventional and alternative low-emission technologies. The cost of hydrogen production by electrolysis will drop significantly with scaling-up to electrolyzer capacity as do fuel cell systems for mobility applications once a volume production is reached. Fuel cell vehicles may become competitive to battery electric vehicles in several long-range applications, with both technologies complementing each other over the portfolio of mobility applications. As a key conclusion the study also revealed that hydrogen can get a key role in the transition of energy and mobility towards a zero-emission world: hydrogen will be a powerful and indispensable carrier for renewable energy and may be the foundation for an international renewable energy and fuel trading system starting as early as 2030.	
Biographical Sketch (Approximately 200 words)	Dr. Brunner is a Managing Director and Co-owner of Hynergy GmbH, a Hydrogen Energy and Mobility Engineering company in Germany, as well as of Cryomotive GmbH, a startup company to develop cryogenic hydrogen storage and refueling technology for long-haul commercial vehicles. From 2016 to 2020 he also served Great Wall Motors as their VP Fuel Cell R&D. In 2019 Dr. Brunner was appointed Strategic Council of FTXT Future Energy, the new Hydrogen Fuel Cell Company of the Great Wall Group. Before co-founding Hynergy GmbH in 2015, Dr. Brunner has been serving BMW Group in various roles for more than 10 years, most recently as head of BMW's Technology Project Hydrogen Fuel Cell. Under Dr. Brunner's supervision several fuel cell electric vehicle prototypes and test fleets as well as novel cryogenic storage and refueling technologies have been developed and demonstrated.	

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Name	Zhongwei Chen	
Affiliation	University of Waterloo	
Invited Plenary Lecture		
Presentation Title	Advanced Platinum and Non-Platinum Catalysts for PEM Fuel Cells	
Abstract (Approximately 200 words)	Polymer electrolyte membrane fuel cells are promising for powering vehicles, residential applications and portable electronic devices, their widespread commercialization hinges, however, on further reduction in materials cost, improvement of durability and increase in overall efficiency. Their key component includes the anode and cathode catalyst layers. The longstanding goal for the catalysts is low cost, high catalytic activity for oxygen reduction reaction (ORR) and viable durability. In this presentation, our approaches to address the main challenges of the catalysts will be outlined by focusing on the following two topics: Pt-based catalysts and non-precious metal catalysts (NPMC). For the former, (i) unique 1D-nanostructured Pt and Pt-based alloy catalysts, (ii) heteroatom-doped nanocarbon supports and (iii) non-carbon nanostructured support materials have been developed and demonstrated to dramatically enhance ORR activity and stability. For the latter, significant progress has been made in the following aspects: (i) novel single-atom catalyst design and synthesis, (ii) active site identification and dynamic structural evolution, (iii) electronic/ geometric structure regulation, (iv) catalyst layer optimization and electrode diagnosis. Fundamental understanding on the catalytic mechanism has been gained, and huge promise of the as-developed NPMCs has been demonstrated to replace Pt/C in practical fuel cells. These achievements will push this field one step ahead.	
Biographical Sketch (Approximately 200 words)	Dr. Zhongwei Chen is Canada Research Chair (CRC-Tier 1) Professor in Advanced Materials for Clean Energy at the University of Waterloo, Fellow of the Royal Society of Canada (FRSC), Fellow of the Canadian Academy of Engineering (FCAE), Director of Waterloo Center for Electrochemical Energy, Associate Editor of ACS Applied Materials & Interfaces, and Vice President of International Academy of Electrochemical Energy Science. His research interests are in the development of advanced energy materials and electrodes for fuel cells, metal-air batteries, and lithium-ion batteries. He has published 3 books, 11 book chapters and more than 350 peer reviewed journal articles with over 30,000 citations with an H-index of 87 (GoogleScholar). He is also listed as inventor for over 60 US/international patents, with several licensed to companies internationally. Dr. Chen has trained over 100 highly qualified personnel. He was the recipient of the 2016 E.W.R Steacie Memorial Fellowship, the member of the RSC's College of New Scholars, Artists and Scientists in 2016, FCAE in 2017, the Rutherford memorial medal from RSC in 2017, which followed upon several other prestigious honors, including the Ontario Early Researcher Award, an NSERC Discovery Supplement Award, the Distinguished Performance and Research Award. In 2018, 2019 and 2020, Dr. Chen was ranked as the Global Highly Cited Researchers by Clarivate Analytics. He was elected as FRSC in 2019.	

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Name	Ahmed F. Ghoniem	
Affiliation	Massachusetts Institute of Technology	
Invited Plenary Lecture		
Presentation Title	**Thermochemical Production of Green and Grey hydrogen**	
Abstract (Approximately 200 words)	Hydrogen is a clean energy carrier needed to fuel long distance ground, water and air transportation, and for gradually replacing fossil fuels in industrial and heating applications. Currently hydrogen is produced mostly using methane-steam reforming and water-gas shift, with significant CO_2 emissions. New technologies are emerging for thermochemical water splitting using methane with CO_2 capture. Metal oxides used in these applications transport oxygen across an ion-conducting membrane, or between chemical-looping reactors, enabling the production of pure hydrogen and CO_2 streams. We will review recent developments in these technologies at the materials, reactors and systems' levels, for the production of grey hydrogen. Solar thermochemical water splitting is considered as a viable alternative for the production of green hydrogen, although challenges remain. We will discuss recent developments that promise significant improvement in efficiency and economics at the reactor and system's scales. Interest in hydrogen carriers such as ammonia is growing, and applications of similar concepts to scale up the production of these carrier present an opportunity to accelerate the deployment of these fuels.	
Biographical Sketch (Approximately 200 words)	Ahmed Ghoniem is the Ronald C. Crane Professor of Mechanical Engineering, Director of the Center for Energy and Propulsion Research and the Reacting Gas Dynamics Laboratory. He received his B.Sc. and M.Sc. degree from Cairo University, and Ph.D. at the University of California, Berkeley. His research covers computational engineering, turbulence and combustion, multiphase flow, clean energy technologies with focus on CO_2 capture, renewable energy and fuels. He supervised more than 100 masters, Ph.D. and post-doctoral students; published more than 500 articles in leading journals and conferences; and consulted for the aerospace, automotive and energy industry. He is fellow of the American Society of Mechanical Engineer, the American Physical Society, and the Combustion Institute, and associate fellow of the American Institute of Aeronautics and Astronautics. He received several awards including the ASME James Harry Potter Award in Thermodynamics, the AIAA Propellant and Combustion Award, the KAUST Investigator Award and the "Committed to Caring Professor" at MIT.	

Name	Craig Gittleman	
Affiliation	General Motors, USA	
Invited Plenary Lecture		
Presentation Title	**Materials research and development focus areas for low cost automotive proton-exchange membrane fuel cells**	
Abstract (Approximately 200 words)	Research and development of fuel cell materials often focuses on designing and developing materials which will reduce the cost or improve the durability of an individual subcomponent. Examples of recent focus areas include non-Pt group metal catalysts, noncarbon catalyst supports, and nonfluorinated membranes. These studies rarely look at the entire system to comprehend the impact of these materials on the cost of ownership to the customer, including vehicle and fuel costs. This talk takes a holistic look at the impact of functional materials on automotive fuel cell systems and provides direction on which material properties will provide the greatest benefit. It also provides guidance on which material classes are the most likely to enable the achievement of systems which will result in the successful commercialization of light-duty fuel-cell vehicles. Additional consideration will be given for materials R&D priorities for heavy-duty applications which show potential for near term commercialization opportunities. Specific focus will be on catalyst and membrane materials that will enable low-cost, durable products.	
Biographical Sketch (Approximately 200 words)	Craig is the Engineering Group Manager for Fuel Cell Materials and Analysis at General Motors. He has responsibility for the R&D of all materials for GM fuel cell stacks and systems. Craig has 25 years of experience in industrial R&D with 21 years of experience in electrochemical energy systems and materials including fuel cells and Li-ion batteries. Craig received his B.S. in chemical engineering from the University of Pennsylvania and his Ph.D. in chemical engineering from the University of California, Berkeley. He spent five years at BOC gases developing adsorbents and sorption processes for gas separation and purification. He joined the GM in 1999, working on on-board fuel processors for fuel cell vehicles and membranes and separators for electrochemical systems including fuel cells and batteries and stack durability. Craig is currently responsible for the advanced technology work within the GM/Honda partnership developing next generation fuel cell systems. Craig is the author of 36 technical publications, 3 book chapters and 29 U.S. patents and patent applications. Craig served as industry co-chair for the USCAR Fuel Cell Tech Team for which he received two special Recognition Awards.	

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Name	Michael D. Guiver	
Affiliation	Tianjin University, China	
Invited Plenary Lecture		
Presentation Title	**Innovations in fuel cell membranes**	
Abstract (Approximately 200 words)	We reported proton exchange membranes with well-defined proton channels running 'through-plane', which provide high proton conduction [*Nat. Commun*. 10 (2019) 842; *Energy Environ. Sci.* 13 (2020) 297-309]. The membrane channels exhibit microporosity, enabling them to retain water at elevated temperatures, allowing good PEMFC performance under low humidity and elevated temperature. We observed that the membranes exhibited unexpected and unusually good free radical oxidative stability as well as stable PEMFC performance. This derives from ferrocyanide units incorporated into the PEM structure. Developing this aspect further, we are now exploring practical ways to stabilize PEMs by incorporating ferrocyanide, as both proton conductors in their own right, and to stabilize membranes through ferrocyanide-ferricyanide redox couples. We have applied this to both perfluorocarbon and hydrocarbon-based PEMs, to enhance oxidative stability under low relative humidity. Currently, we are designing AEMs with aligned hydroxide-conducting channels, which appear to be robust and have promising properties.	
Biographical Sketch (Approximately 200 words)	Dr. Michael Guiver obtained his BSc (London University) and MSc (Carleton University) in Chemistry, and his PhD in Polymer Chemistry from Carleton University in 1988. He served 12 years as an Editor for the *Journal of Membrane Science* (2009–2020). He previously served on ACS Editorial Boards, and is currently a member on the International Advisory Board of *Macromolecular Research* and on the Editorial Boards of *Polymers* and *Membranes*. He is a Fellow of the Royal Society of Chemistry and an ACS Poly Fellow. He spent most of his career at the National Research Council Canada, and left in 2014 as a principal research officer. In 2009-2013, he was a visiting professor at the Department of Energy Engineering, Hanyang University, Korea. In September 2014, he relocated to Tianjin University, China as a full-time National 1000-plan Foreign Expert Professor. He has published over 250 papers and his primary expertise is in polymer chemistry and design and his research interests are in polymeric membrane gas separations and ion-conducting membranes for fuel cells. He works on PEMs and AEMs, and is also investigating the simple stabilization of hydrocarbon-based membranes, allowing their practical use.	

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Name	Prof David Hart	
Affiliation	E4tech	
Invited Plenary Lecture		
Presentation Title	**How fuel cells can help both recovery and climate in a post-covid world**	
Abstract (Approximately 200 words)	Fuel cell shipments have been on an upward trajectory for a decade. The signs at the end of 2019 suggested further strong growth in 2020. But as the COVID-19 pandemic took hold, orders dropped. As they picked up, supply chains were disrupted and manufacturing delayed. Nevertheless, the final shipment figures in our Fuel Cell Industry Review did still show an uptick over 2019 – a very strong sign of the increasing competitiveness of fuel cells in different end uses and markets. This is a good sign for future sales, but particularly promising is the increasing political and industrial realization that fuel cells can play an important part in post-covid economic recovery as well as in the battle against climate change. The role of the fuel cell industry in creating and maintaining jobs, in replacing existing but more polluting technologies as drivers of industrial growth, and in accelerating a shift to lower-carbon and zero-emissions applications will be essential as society reinvents itself post-covid. This talk will put the fuel cell industry into its post-covid context, and suggest what steps might be taken to ensure it plays the fullest possible role.	
Biographical Sketch (Approximately 200 words)	David Hart is a Director of E4tech, a Switzerland- and UK-based business consulting company specialising in sustainable energy, and a Visiting Professor at Imperial College London. He is responsible for E4tech's fuel cell and hydrogen energy practice, and has been an advisor, consultant and researcher on fuel cells and hydrogen energy for 25 years, leading and conducting projects in different industry sectors for governments, corporations and investors worldwide. Current work includes support for major energy players in developing hydrogen strategies, analysis of supply chain opportunities for specialists in the fuel cell industry, and policy options for economic growth based on hydrogen and fuel cell deployment. David has sat on venture capital investment committees and clean energy company boards, is a Director of the International Association for Hydrogen Energy and is lead author of E4tech's widely-respected Fuel Cell Industry Review.	

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Name	Shigeki Hasegawa	
Affiliation	Toyota Japan	
Invited Plenary Lecture		
Presentation Title	**Physical Modeling of Fuel Cell System and Application to Product System and Control Development**	
Abstract (Approximately 200 words)	1D physical modeling methods of fuel cell stack and balance of plants (air-supply system, H2-supply system and cooling system) is investigated. To ensure simulation of life-long system operation in permissible calculation time and accuracy, proper resolution of modeling methods is chosen and in-house high-speed numerical solvers are developed. This model is validated by actual fuel cell system data gathered in a variety of operating conditions (low to high loads, operating temperatures and ambient pressures). High accuracy is confirmed across these conditions. With proper resolution of modeling methods and high-speed numerical solvers, the model executes approximately 30 times faster than real time. In addition to serving as a fuel cell system simulator, the same modeling and numerical methods are introduced to control software implemented in a production engine control unit (ECU) for fuel cell system control. These models run in real-time and act as 'virtual sensors' with which any state variables at any components can be measured and used for on-board calculations. Based on these estimated state variables, simple and high-accuracy feed-forward controllers are developed to improve control response and reduce controller calibration effort. Finally, the future target of a model-based development process is discussed, in which a combination of 1D and 3D-CFD/FEM based fuel cell system models are utilized as a fundamental piece of the overall development process.	
Biographical Sketch (Approximately 200 words)	Specialized Fields - Chemical Engineering - Electrochemistry - Computational Analysis Education - 2002 : B.A. in Chemical Engineering, Kyoto University - 2004 : M.S in Energy Science, Graduate School of Energy Science, Kyoto University Experience (TOYOTA MOTOR CORPORATION) - 2004-2013 : Fuel Cell Stack Component Development for Advance System - 2012-2014 : Fuel Cell System and Controller Development for Advance System - 2015-Present : Fuel Cell System and Controller Development for Product System	

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<table>
<tr><td>Name</td><td>Jun Liu</td><td rowspan="3"></td></tr>
<tr><td>Affiliation</td><td>University of Washington
Pacific Northwest National Laboratory</td></tr>
<tr><td colspan="2">Invited Plenary Lecture</td></tr>
<tr><td>Presentation Title</td><td colspan="2">Electrons or Hydrogen – The Choices for Future Energy Storage</td></tr>
<tr><td>Abstract (Approximately 200 words)</td><td colspan="2">Energy storage has attracted wide attention in the last decade. Traditional technologies like pumped hydro are mature and economic but they are not available everywhere. Recently lithium ion batteries have played an important and dominant role due to their flexibility and potential for a wide range of applications. The most difficulty problem is long duration energy storage. Although the great efforts have been made and extensive analysis has been performed, it is not clear what technologies will become viable for long term energy storage. This talk will summarize the current status of energy storage materials and technologies, and provide some insights of recent thinking on how to solve the grand energy storage challenge.</td></tr>
<tr><td>Biographical Sketch (Approximately 200 words)</td><td colspan="2">Dr. Jun Liu is a Washington Foundation Innovation Chair and Campbell Chair Professor at the University of Washington (UW), and a Battelle Fellow at the Pacific Northwest National Laboratory (PNNL). He also serves as the Director for Innovation Center for the Battery500 Consortium and President of the International Coalition for Energy Storage. Dr. Liu received the PNNL Life-Time Achievement Award, Battery Division Technology Award from The Electrochemical Society (ECS), two R&D100 Awards and the DOE EERE Exceptional Achievement Award. He is an elected member of Washington Academy of Science, a Materials Research Society (MRS) Fellow, an Electrochemical Society (ECS) Fellow, and an American Association for the Advancement of Science (AAAS) Fellow. He has been ranked as a highly cited researcher in the world since 2014. He was named a Distinguished Inventor of Battelle in 2007, and was two times selected as PNNL's Inventor of the Year.</td></tr>
</table>

Name	Asmae Mokrini	
Affiliation	National Research Council Canada	
Invited Plenary Lecture		
Presentation Title	**Novel Manufacturing Opportunities for PEM Cost Reduction and Durability Improvement**	
Abstract (Approximately 200 words)	Fuel cell electric vehicles (FCEV) deployment is expanding more quickly than ever, the global FCEV stock nearly doubled to more than 25,000 units at the end of 2019, with 12,950 new vehicles sold worldwide (2,100 in the US). However, it still accounts for just 0.5% of new low-carbon vehicles sales. Fuel cell cost, durability and the availability of hydrogen refueling infrastructure are still challenges to be overcome to enable a more extensive market penetration. In terms of PEMFC cost, research has been extensively directed towards lower cost materials, such as partially or non-fluorinated ionomers to replace high cost perfluorosulfonic acid (PFSA) ionomers, or low or non-Platinum catalysts to reduce or eliminate Platinum from catalyst layer, or metallic bipolar plates to replace graphite to name a few examples. However, all of these approaches can often lead to a compromised durability. Research on alternative manufacturing processes can present great opportunities to significantly reduce cost, while keeping or improving the durability. This talk presents the work carried out at the National Research Council to develop innovative manufacturing approaches to produce proton exchange membranes, the validation and scale-up of the process with different ionomers, and the results obtained from performance and durability assessment. The Techno-economic analysis of the scaled-up process will be presented, as will the commercialization feasibility, for different FCEV annual production scenarios.	
Biographical Sketch (Approximately 200 words)	Asmae Mokrini is a Team Lead and a Senior Research Officer at the Automotive and Surface Transportation Research Center of the National Research Council Canada. She holds a master's degree in Polymer Science and Technology from the University of Menendez-Pelayo in Madrid and a PhD in Chemical Engineering from the University of Barcelona. She joined the National Research Council of Canada as a Research Officer in 2003, where she led and contributed to several R&D projects related to materials and manufacturing process developments for fuel cells, and different battery technologies, and established many collaborations with industry, Other Government Departments and national and international R&D organizations. With Over twenty years of achievements in research and development on Zero Emission electrochemical energy storage and generation devices for automotive applications, she holds several patents and is the author of +150 publications, conference proceedings and industrial proprietary reports.	

Name	Dr. Sunita Satyapal	
Affiliation	Director, Hydrogen and Fuel cell Technologies Office Office of Energy Efficiency and Renewable Energy U.S. Department of Energy	
Invited Plenary Lecture		
Presentation Title	U.S. Department of Energy's Hydrogen and Fuel Cell Perspectives	
Abstract (Approximately 200 words)	Hydrogen and fuel cells are emerging, versatile examples within a portfolio of advanced and sustainable energy options. Dr. Sunita Satyapal will provide an overview of hydrogen and fuel cell research, development, demonstration and deployment (RDD&D) activities led by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE). The presentation will discuss how EERE's RDD&D efforts are advancing U.S. commitment to tackling the climate crisis through the DOE Hydrogen Program's H2@scale vision for clean hydrogen across the economy, and the Hydrogen Energy Earthshot seeking to cut the cost of clean hydrogen to $1 per 1 kilogram in one decade. The presentation will also cover examples of H2@Scale projects demonstrating hydrogen's emission reduction and economic growth potential in hard to decarbonize sectors such as steel manufacturing and heavy duty applications, as well workforce development and international collaboration activities.	
Biographical Sketch (Approximately 200 words)	**Dr. Sunita Satyapal** is the Director for the U.S. Department of Energy's Hydrogen and Fuel Cell Technologies Office within the Office of Energy Efficiency and Renewable Energy and is responsible for $150 million per year in hydrogen and fuel cell R&D. She has two and a half decades of experience across industry, academia and government, including at United Technologies managing research and business development, and as a visiting professor. She has served as the Chair – is currently the co-Chair – of the International Partnership for Hydrogen and Fuel Cells in the Economy, a partnership among over 20 countries to accelerate progress in hydrogen. She received her Ph.D. from Columbia University and did postdoctoral work in Applied and Engineering Physics at Cornell University. She has numerous publications, including in Scientific American, 10 patents, and a number of recognitions including a Presidential Rank Award.	

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AUGUST 16-20, 2021 | WATERLOO, CANADA

Name	Professor Dr. Detlef Stolten	
Affiliation	Juelich Research Center, Director of the Institute of Techno-Economic Systems Analysis (IEK-3)	
Invited Plenary Lecture		
Presentation Title	**Hydrogen Becoming a Commodity: A Requisite for Future Carbon-neutral Energy Systems Getting Reliable and Affordable**	
Abstract (Approximately 200 words)	Owing to ever more palpable climate change and its economic consequences there is a worldwide ambition to making energy systems renewable. The main pillars are photo-voltaics, windmills, to a lesser degree bio sources and hydropower. The first technologies provide cheap but fluctuating electricity; and areas of extremely high insulation or average wind speeds generally are sparsely populated for good, though exactly these reasons can provide cheap electricity. Hence, converting this electricity to a storable gas like hydrogen and transport it to highly populated regions - which represent energy sinks – is an important strategy to making the future renewable energy system affordable and reliable. Furthermore, it reduces the energy storage requirements for compensating sustained lulls of renewable energy. This talk will link a study on German energy provision resulting into 13 million tons of hydrogen to be imported with one on international hydrogen production, outlining the technologies, cost and casting a light on societal aspects and requirements to make such projects happen in the countries of origin. As for the production of hydrogen detailed studies have been conducted for over 20 regions worldwide. This comprises the placing of the renewable energy, selecting the necessary infrastructure means including water supply for electrolysis and evaluating the cost for production and shipping. The approach, select specific results and lessons learned will be presented.	
Biographical Sketch (Approximately 200 words)	Professor Dr. Detlef Stolten is the director of the Institute of Techno-Economic Systems Analysis (IEK-3) at the Juelich Research Center, Germany, and chair for fuel cells at RWTH Aachen University since 2000. His research focuses on electrochemistry and process engineering for different types of fuel cells and electrolyzers. Energy systems analysis and energy strategy form a new research topic since 2010. It focuses on interconnecting the energy sectors and the role of storage encompassing gas and electric grid modeling, renewable power input, transportation energy requirements and storage via hydrogen, methane, LOHC and other options incl. renewable hydrogen production via electrolysis. For 12 years he worked in the industry with Bosch and Daimler Benz/Dornier. He is chairman of the Executive Committee of the Technology Collaboration Program ‘Advanced Fuel Cells’ of the International Energy Agency, Vice President of the International Association of Hydrogen Energy, member of the advisory board of the society Process and Chemical Engineering of the Association of German Engineers, member of the supervisory board of the Wuppertal Institute for Climate, Environment and Energy and member of the scientific advisory board of the Max Planck Institute for Dynamics of Complex Technical Systems. He published over 340 scientific articles and edited six books on the topics of hydrogen, fuel cells, carbon capture and on the transition to renewable energy systems.	

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Name	Xueliang Andy Sun	
Affiliation	University of Western Ontario, Canada	
Invited Plenary Lecture		
Presentation Title	Single Atom Electrocatalysts for PEM Fuel Cells: Opportunity, Challenge and Progress	
Abstract (Approximately 200 words)	Fuel cells are electrochemical devices that convert the chemical energy of a fuel directly to electrical power. However, there are still challenges ahead which are hindering the market implementation of PEMFC technology, mainly high cost of materials and the durability during fuel cell life-time operation. The high cost is primarily associated with precious metal catalysts (Pt or Pt alloys). It is well accepted that the catalytic efficiency and selectivity of catalysts are not only size dependent, but also dependent on shape and composition. Key challenges to be overcome include the ability to accurately control synthesis of the shape and composition of Pt-based nanostructures (e.g. from nano size down to Pt single atom or clusters). The noble atom catalysts have attracted rapidly increasing attention due to their unique catalytic properties and maximized utilization for low-cost. This invited talk will focus on Pt-based electrocatalysts from nanoparticles to single atoms, with an overview of the development of single atom catalysts in fuel cells. In particular, the collaborative work with Ballard Power Systems on atomic layer deposition technique (ALD) will be presented for high density of isolated single atom catalysts and dimers, with emphasis of understanding of catalytic active sites and insights into the design of high performance of novel catalytic systems will be provided along with future perspectives.	
Biographical Sketch (Approximately 200 words)	Dr. Xueliang (Andy) Sun is a Full Professor and senior Canada Research Chair (Tier I) at the University of Western Ontario, Canada. Dr. Sun is a Fellow of Royal Society of Canada and Fellow of the Canadian Academy of Engineering. Dr. Sun received his Ph.D degree in Materials Chemistry at the University of Manchester, UK, in 1999. Dr. Sun's research is focused on advanced materials for energy conversion and storage including fuel cells and Li batteries. Dr. Sun was named as one of "Highly Cited Researchers" in 2018-2020. Dr. Sun is an author and co-author of over 500 refereed-journals (e.g. Nature Energy, Nature Communications, Advanced Materials, J. Am. Chem. Soc., Angew. Chem., Nano Letter, Energy & Environmental Science) with citations of over 33,000 times and H-index of 92. He edited 4 books and published 18 book chapters as well as filed 24 patents. Dr. Sun received various awards such as Award for Research Excellence in Materials Chemistry Winner from Canada Chemistry Society (2018) and University Hellmuch Prize for Achievement in Research (2019). Dr. Sun is a vice Chairman of the International Academy of Electrochemical Energy Science (IAOEES). He also serves as an Editor-in-Chief of "Electrochemical Energy Review" under Spring-Nature.	

Name	Xiao-Zi Yuan	
Affiliation	National Research Council Canada	
Invited Plenary Lecture		
Presentation Title	**Quality Control of PEM Fuel Cell Components**	
Abstract (Approximately 200 words)	As industry is commercializing the proton exchange membrane (PEM) fuel cell technology, especially for transportation applications, the need for quality control (QC) of the PEM fuel cell and its components is stringent. QC is an essential part of fuel cell industrialization, providing means to reduce cost of components, enhancing the reliability of the final product, and offering specification guidance for new entrants in the supply chain. Also, the fuel cell industry has an imperative demand arising from the lack of standard methods, protocols and tools for the incoming, in-process and final QC of PEM fuel cell components. In support of the industrialization of fuel cell technology, National Research Council Canada (NRC) has been reorienting its fuel cell activities towards manufacturing issues to tackle specific challenges linked to the component specification definition, standardization and QC. Around QC, NRC has worked closely with fuel cell OEMs, suppliers, and knowledge providers via international collaborations, conducted a number of projects related to QC and developed tools and methods for component QC. This talk presents some of the activities conducted at NRC around QC, in particular, the development of book of attributes for fuel cell components, including membrane, catalyst coated membrane, catalyst layer, gas diffusion layer, bipolar plate, ink, and gasket.	
Biographical Sketch (Approximately 200 words)	Dr. Xiao-Zi Yuan is a Research Officer at the Energy, Mines & Environment (EME) Research Centre of the National Research Council Canada (NRC). Dr. Yuan received her B.S. and M.Sc. in Corrosion and Protection from Nanjing University of Technology in 1991 and 1994, respectively and her Ph.D. in Material Science from Shanghai Jiaotong University in 2003. Beginning in 2004, she carried out a three-year postdoctoral research program supported by Natural Sciences and Engineering Research Council (NSERC). In 2007, Dr. Yuan joined NRC. At NRC, she has participated and led many projects related to fuel cells and batteries. Her research interests include PEM fuel cells, Li-ion batteries, Zn/Li air batteries, vanadium redox flow batteries, and other types of electrochemical devices and energy storage systems. Her research areas range from cell design, electrode material and structure to cell testing, diagnosis, and durability. So far Dr. Yuan has published over a hundred and thirty research papers in refereed journals, and produced four books and six book chapters. In 2014 and 2016, Dr. Yuan was listed as Highly Cited Researcher by Thomson Reuters under the Engineering Section.	

Name	Piotr Zelenay	
Affiliation	Los Alamos National Laboratory	
Invited Plenary Lecture		
Presentation Title	**Durability of PGM-Free ORR Catalysts: Recent Progress**	
Abstract (Approximately 200 words)	While the electrocatalytic activity of platinum group metal-free (PGM-free) catalysts for oxygen reduction reaction (ORR), in particular those obtained through the widely used high-temperature treatment approach, has reached levels close to practical (at high catalyst loadings), their durability under the operating conditions of the polymer electrolyte (PEFC) fuel cell cathode has continued to present a very significant challenge. The catalysts tend to lose approximately half of their initial activity during the first 100 hours of operation at a constant PEFC voltage and even more when subjected to voltage cycling in air. Very significant improvements to PGM-free catalyst performance durability are thus required if they are to become viable for acidic PEFCs. In this presentation, we will summarize the present state of the PGM-free catalyst durability, introduce methods of assessing its assessment (including the performance metrics), and describe catalysts synthesized at Los Alamos a novel 'dual-zone' modification of the high-temperature synthesis of PGM-free catalysts. The modification has resulted in significantly enhanced durability of high-temperature catalysts, as demonstrated in H_2-air fuel cells testing both at a constant voltage and during voltage cycling. We will follow with the discussion of possible origins of the much-improved performance durability imparted by this approach.	
Biographical Sketch (Approximately 200 words)	Dr. Piotr Zelenay holds Ph.D. and D.Sc. degrees in Chemistry from the University of Warsaw, Poland. He has been associated with Los Alamos National Laboratory (LANL) for the past 24 years, since 2016 as a Laboratory Fellow. His research has focused on fundamental and applied aspects of polymer electrolyte fuel cells, electrochemistry, electrode kinetics, and especially in electrocatalysis, including development of catalysts for oxygen reduction reaction, methanol and dimethyl ether oxidation. Dr. Zelenay has published ca. 200 research papers, including many in renowned scientific journals such as *Nature*, *Science*, *Chemical Reviews*, *Accounts of Chemical Research*, *Angewandte Chemie*, *Energy & Environmental Science*, and *Advanced Materials*. He has co-authored over 450 presentations, including ca. 200 invited, keynote, and plenary lectures. Since joining LANL in 1997, he has successfully led numerous research projects, including large ones. Among them, he has co-directed (with his Argonne partner) and provided scientific lead for ElectroCat since its inception in 2016. Dr. Zelenay received numerous awards and recognitions, including Fellowship of the International Society of Electrochemistry (2021), DOE Hydrogen and Fuel Cells Program Fuel Cell R&D Awards (2010 & 2020); R&D 100 Award (2017); National Professorship in Chemistry by the President of Poland (2015); Los Alamos National Laboratory Fellows Prize (2015); and Fellowship of the Electrochemical Society (2014).	

Abstracts of Keynote Sessions

Biographies of Keynote Speakers

Name	Linfa Peng	
Affiliation	Shanghai Jiao Tong University	
Invited Keynote Lecture		
Presentation Title	**WFCC2021-201: Manufacturing of thin metallic bipolar plate for PEM fuel cells: development of forming and coating processes**	
Abstract (Approximately 200 words)	The industrial applications of PEMFC have attracted tremendous capitals and research attention. Due to the unique advantages of ultra-thin, high strength, easy-to-mass-produce, etc., metallic bipolar plates (BPs) are the promising solution for the applications requiring high power density. To realize both high density and long durability, many challenges remain to be conquered for metallic BPs. The gap between BP design and manufacturing is the first fundamental issue. The multi-stage forming is adopted to realize optimized BP designs of large-area micro channels with a higher aspect ratio. Based on a systematic investigation on the deformation, friction and fracture mechanics at micro/meso scale, the coupling effects of material, plastic mechanics, loading conditions, geometric factors, etc. in the multi-stage forming were explored. An optimization roadmap of formability, springback and accuracy of metallic BPs was also given. Additionally, the conductivity, corrosion and ion emission resistance of metallic BPs require a coating with both high performance and low cost. Many candidates such as pure carbon, doped carbon and noble metals were investigated. The mechanisms of how the different coating elements and microstructures affecting the mechanical, electrical and electrochemical performances of BPs were investigated. The coating design, evaluation and fabrication towards industrialization are also discussed.	
Biographical Sketch (Approximately 200 words)	Linfa Peng is a full professor at the State Key Laboratory of Mechanical System and Vibration in Shanghai Jiao Tong University. He also works as the deputy director of the youth working committee and a member of the micro/nano fabrication branch of the China Society for Technology of Plasticity. He is a winner of the Excellent Young Scientists Fund of the National Natural Science Foundation of China. He is also entitled a distinguished Young Professor of Chang Jiang Scholars Program by the Chinese Education Ministry. His research interests include micro/meso metal forming process and new-energy equipment development. The metallic BP manufacturing technologies developed by Prof. Peng have been widely applied in the fuel cell cars developed by SAIC, SRP, GAC, GWM, etc. He has won the 2015 Natural Science Award (First Class) of Chinese Education Ministry, the 2017 Automobile Industrial Invention Award (First class) of China Society of Automobile Engineers and the 2019 Shanghai Technical Invention Award (Special Prize).	

Name	Prof. Dr. Bruno G. Pollet AFIChemE FRSC	
Affiliation	Norwegian University of Science and Technology (NTNU)	
Invited Keynote Lecture		
Presentation Title	**WFCC2021-202: Sonocatalysis – A "sound" process for producing hydrogen and catalytic materials for fuel cells and electrolyzers**	
Abstract (Approximately 200 words)	It is well accepted in the ultrasonic and sonochemistry (the application of ultrasound in chemistry) communities that ultrasonic waves propagating in liquids lead to acoustic cavitation, sonolysis (radical generation), areas of extreme mixing close to the ultrasonic source (transducer), degassing, surface cleaning (and erosion), and rises in bulk temperature. The publications of 'The use of ultrasound for the fabrication of fuel cell materials' (2010) and the 'Sonochemical and sonoelectrochemical production of hydrogen' (2019) triggered an international interest in the use of ultrasound, sonochemistry and sonoelectrochemistry (ultrasound combined with electrochemistry) for the synthesis of energy materials and useful gases. This is due to the fact that these methods are efficient and do not require intensive labour as well as the use of large amounts of toxic and environmentally hazardous solvents. This presentation highlights the development of novel electrolyzer and fuel cell catalysts and electrodes as well as the production of hydrogen by utilizing power ultrasound (20kHz–1MHz). It also highlights that care should be taken when ultrasonicating (in the form of a laboratory-grade ultrasonic bath, or an ultrasonic probe, sonifier) catalyst ink slurries prior to deposition for the fabrication of fuel cell and electrolyzer electrodes; as it has been shown that ultrasound leads to catalyst dissolution and ionomer degradation induced by acoustic cavitation.	
Biographical Sketch (Approximately 200 words)	Bruno G. Pollet (Google Scholar h-index=42) is a full Professor of Renewable Energy at the Norwegian University of Science and Technology (NTNU), Leader of "NTNU Team Hydrogen" (the largest hydrogen R&D cluster in Norway), Extraordinary Professor in Hydrogen Energy at the University of the Western Cape (South Africa) and has been recently appointed as President of the Green Hydrogen Division of the International Association for Hydrogen Energy. His research covers a wide range of areas from the development of novel materials for low-temperature fuel cells and water electrolyzers, hydrogen production from (non-)pure waters, organics and bio-wastes, to fuel cell and electrolyzer systems, demonstrators and prototypes. He co-founded the Birmingham Centre for Hydrogen and Fuel Cell Research (UK) and was Director of HySA Systems Integration & Technology Validation Competence Centre (South Africa). He has worked for Johnson Matthey Fuel Cells Ltd (UK) and other various industries worldwide. He gained his PhD in Physical Chemistry in the field of Electrochemistry and Sonochemistry at Coventry University (UK) and undertook his PostDoc in Electrocatalysis at the Liverpool University Electrochemistry (UK). He serves on several associations and industry boards as well as editorial boards of international journals (Elsevier, Royal Society of Chemistry, Springer & Wiley).	

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AUGUST 16-20, 2021 | WATERLOO, CANADA

Name	Samaneh Shahgaldi	
Affiliation	University of Quebec at Trois-Rivieres	
Invited Keynote Lecture		
Presentation Title	**WFCC2021-203: Impact of Ionomer Ratio, Type and Design on Fuel Cell Performance and Durability under Different Operational Conditions**	
Abstract (Approximately 200 words)	Proton exchange membrane fuel cells offer a broad range of advantages for the environment and energy security. However, durability and cost are the two main challenges for mass production and commercialization. These two interrelated issues are greatly impacted by various parameters, mainly associated with the catalyst layer which is the main component of membrane electrode assembly. The state-of-the-art catalyst layers are made of supported Pt nanoparticles and perfluorosulfunic acid ionomers. Cost reduction has been focused on the reduction of catalyst loading which is often accompanied with a reduction in durability. In this talk, we take a holistic look at the impact of the ionomer used in catalyst layers on fuel cell performance and durability, as the ionomer affects the ionic conductivity, catalyst utilization, mass transport, and immobilization of catalyst particles. Different ionomer types, ratios and gradient designs are applied in the catalyst layers and their fuel cell performances will be discussed in detail under different operational conditions. In addition, we provide an effective insight into the degradation of catalyst layer with different platinum loadings made with various types of ionomer by investigating the morphological and microstructural characteristics under freeze-thaw cycles. This talk provides direction on the best ionomer selection based on the type of catalysts and operational conditions.	
Biographical Sketch (Approximately 200 words)	Samaneh Shahgaldi is an Associate Professor and Canada Research Chair Tier II at the Chemistry, Bio-Chemistry and Physics department at the University of Quebec à Trois-Rivières. She obtained her Ph.D in Chemical engineering at 2012 and worked as a research associate at Fuel Cell and Green Energy Lab at University of Waterloo for 4 years. She was also a Senior Research Scientist at Cummins/ Hydrogenics dealing with different PEM Fuel Cell and PEM Water electrolyzer projects. Dr. Shahgaldi is an award-wining researcher with unique interdisciplinary expertise in nanomaterials, organic chemistry, and chemical engineering. She has made foundational contributions to research in synthesis of novel nanomaterials and engineer the surface properties for fuel cells and hydrogen storage applications. She is also directed R&D projects in the development of next-generation membrane electrode assembly (MEA) and components.	

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Name	Shuhui Sun	
Affiliation	Institut National de la Recherche Scientifique (INRS), Canada	
Invited Keynote Lecture		
Presentation Title	**WFCC2021-204: Low-Pt and Pt-free Catalysts for Hydrogen Fuel Cells**	
Abstract (Approximately 200 words)	Hydrogen (H_2) fuel cells hold promising applications in transportation and stationary, however, their widespread commercialization is greatly hindered by the high cost. Platinum (Pt) represents one of the largest cost components of a fuel cell, therefore, many R&D activities have been focusing on strategies that will increase the activity and utilization of platinum group metal (PGM) catalysts, and PGM-free catalysts for long-term applications. In this talk, I will present our work to address the main challenges of the catalysts via two approaches: low-Pt catalysts and Pt-free catalysts. On one hand, in collaboration with GM, we have developed various unique nanostructured Pt-based catalysts, including Pt nanowires, nanotubes, alloys and single atoms, as well as novel catalyst supports, to significantly increase the activity and stability of the Pt-based catalysts for ORR in fuel cells. Based on the major breakthroughs on Fe/N/C catalyst achieved by the Dodelet team at INRS (with the MEA activity and performance approaching that of Pt catalyst) [*Science 2009, Nature Commun 2011*], recently, in collaboration with Ballard Power Systems and Toyota, we have made significant progress on catalyst stability. Specifically in the following aspects: (i) identifying the active sites, (ii) understanding the fuel cell degradation mechanisms experimentally and theoretically, (iii) developing approaches to improving the stability of the Fe/N/C catalyst, such as pore size control, and fluorination, and (iv) catalyst layer and electrode optimization, such as catalyst hydrophobicity adjustment, Fe/N/C and ultra-low loading Pt/C hybrid catalyst.	
Biographical Sketch (Approximately 200 words)	Dr. Shuhui Sun is a Full Professor at the Institut National de la Recherche Scientifique (INRS), center for Energy, Materials, and Telecommunications (Montreal, Canada), where he directs the Laboratory of Nanotechnology for Sustainable Energy. Dr. Sun is a member of the Royal Society of Canada's College of New Scholars, the Vice President of the International Academy of Electrochemical Energy Science (IAOEES), and the Executive Editor-in-Chief of Electrochemical Energy Reviews (Springer-Nature). He is among the world's top 2% scientists. Dr. Sun's research interests focus on developing functional materials for energy conversion and storage, including hydrogen fuel cells (low-Pt and Pt-free catalysts, ionomers), hydrogen generation, lithium batteries, and metal-air batteries. He has published over 220 peer-reviewed journal articles (e.g., Nature Communications, Energy & Environmental Science, Advanced Materials, Advanced Energy Materials, J. Am. Chem. Soc., Angew. Chem), with citations of over 12,000 times and an H index of 56. He has edited 3 books, published 14 book chapters, and holds several patents. His recent awards include the Canadian Catalysis Lectureship Award (2020), ECS-Toyota Young Investigator Fellow (2017), IUPAC Novel Materials Youth Prize (2017), member of Global Young Academy (2017), as well as Canada Governor General's Academic Gold Medal, etc.	

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Name	Wei Yan	
Affiliation	Institute for Sustainable Energy, Shanghai University, China	
Invited Keynote Lecture		
Presentation Title	**WFCC2021-205: CO- and H_2S-Tolerant Electrocatalysts for Hydrogen Oxidation Reaction in Proton Exchange Membrane Fuel Cells**	
Abstract (Approximately 200 words)	Proton Exchange Membrane Fuel Cell (PEMFC) is considered to be a promising energy conversion device due to its high energy/power densities, high efficiency and low/zero emission. Currently, the most practical catalysts for PEMFCs are still Pt-based ones. Nowadays, hydrogen fuel for PEMFCs mainly comes from steam reforming of hydrocarbons, which inevitably contains impurities. Regarding the impurities, CO and H_2S have received particular attention because trace amounts of them in hydrogen fuel can poison the Pt-based catalysts. Extensive researches have been carried out to address the issue of CO poisoning in PEMFCs, and it is found that Pt-based multi-metallic catalysts especially carbon-supported Pt-Ru alloy catalysts can give enhanced resistance to CO-poisoning. The mechanism of CO tolerance at Pt-Ru alloy catalysts have been well studied. However, H_2S poisoning has not been given sufficient attention. As reported, even 0.1 ppm H_2S in hydrogen fuel could lead to decrease in cell potential [2]. Therefore, it is necessary to give more effort to developing H_2S tolerant electrocatalysts for PEMFCs. In our effort, a transition-metal-oxide-supported Pt-Ru alloy electrocatalysts with both high CO- and H_2S-tolerant capabilities for PEMFCs has been developed. Experimental results show that the transition-metal-oxide support can play a vital role in offering Pt-Ru alloy with additional strong resistant ability to H_2S poisoning, suggesting that such a transition-metal-oxide support should be a possible approach to mitigate H_2S poisoning in PEMFCs.	
Biographical Sketch (Approximately 200 words)	Dr. Wei Yan is currently an associate professor in the Institute for Sustainable Energy at the Shanghai University. She received her Ph.D. degree in Electrochemistry from Wuhan University in 2005 and carried out her postdoctoral research in Nanjing University from 2005 to 2007. Her research interest is in the area of research and development of advanced electrode materials for electrochemical energy storage and conversion systems, including: 1) electrocatalysts for PEMFCs and Zinc-air batteries; 2) carbon materials for lead-carbon batteries; 3) scaffolds for Li/Na/K metal anodes. Dr. Wei Yan is now working with Prof. Jiujun Zhang on research and development of CO and H_2S-tolerant electrocatalysts for PEMFCs with high efficiency.	

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AUGUST 16-20, 2021 | WATERLOO, CANADA

<table>
<tr><td>Name</td><td>Shiming Zhang</td><td rowspan="3"></td></tr>
<tr><td>Affiliation</td><td>Institute for Sustainable Energy, Shanghai University, China</td></tr>
<tr><td colspan="2">Invited Keynote Lecture</td></tr>
<tr><td>Presentation Title</td><td colspan="2">WFCC2021-206: Modulation Strategy of Active sites in Carbon-based Electrocatalysts for Oxygen Reduction Reaction</td></tr>
<tr><td>Abstract (Approximately 200 words)</td><td colspan="2">Carbon-based electrocatalysts have shown the great potential of replacing platinum (Pt) in catalyzing the sluggish oxygen reduction reaction (ORR) at the cathodes of polymer electrolyte membrane fuel cells (PEMFCs). Active sites directly link to the catalytic activity of electrocatalysts. Generally, there are different types of active sites in the nonprecious metal carbon catalysts including metal-N_x species, N-C groups and so on, which play important roles in synergistically modulating the catalytic activity. In this talk, it will be discussed for the modulation strategy of different active sites to guide the design and development of the high-performance carbon-based ORR electrocatalysts.</td></tr>
<tr><td>Biographical Sketch (Approximately 200 words)</td><td colspan="2">Dr. Shiming Zhang is currently an Associate Professor in College of Science/ Institute for Sustainable Energy at Shanghai University. Dr. Zhang received his Ph.D. in Electrochemistry from Wuhan University in 2014, with an experience of exchange student during 2013 at Nanyang Technological University, Singapore. He then mainly carried out the postdoctoral research from 2015 to 2019 at Shanghai Electrochemical Energy Device Engineering Technology Research Center, Shanghai Jiao Tong University. He was selected for the Shanghai Rising-Star Program in 2018. His expertise areas are electrochemical energy technologies, such as electrocatalysis, fuel cells, and Li-ion batteries.</td></tr>
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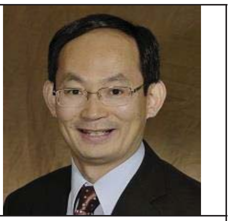
Name	Dmitri Bessarabov	
Affiliation	HySA Center at NWU, South Africa: Director	
Invited Keynote Lecture		
Presentation Title	**WFCC2021-207: PEM technology for water electrolysis and electrochemical hydrogen compression**	
Abstract (Approximately 200 words)	PEMs (proton-exchange membranes) are one of the key components in zero-gap acidic water electrolysis (WE) and electrochemical hydrogen compression (EHC). These membranes act as electrical (electronic) insulators and gas barriers allowing oxygen and hydrogen separation and high-pressure discharge of hydrogen at the cathode. They also act as charge carriers (H^+) and responsible for a large share of the IR-drop in the electrochemical cells. An overview of PEM technology suitable for both WE and EHC will be discussed. Challenges such as hydrogen cross over and hydrogen cathode oversaturation that are similar to both PEMWE and EHC will be discussed as well as their measuring techniques. Opportunities for low temperature and high temperature processes as well as gas separation efficiency achieved in the EHC process will also be discussed.	
Biographical Sketch (Approximately 200 words)	Prof. Dmitri Bessarabov joined DST HySA Infrastructure Center of Competence in 2010. He was recruited for a position from Canada. He received his PhD in 1996 specializing in membrane technology for gas separation from University of Stellenbosch in South Africa. In 2001 Dmitri joined Aker Kvaerner Chemetics in Vancouver, Canada, to work in the area of membrane technology for chlor-alkali industry. In 2006 Dmitri joined Ballard Power Systems in Canada (and afterwards AFCC – Automotive Fuel Cell Cooperation Corp) where he was leading an R&D group on MEA Integration and Evaluation, working for HyWay5 automotive program with focus on CCMs. His main areas of professional interest include: Fuel cells, PEM Electrolysis, Hydrogen Storage, Hydrogen Infrastructure, Membranes, Separations, Applied Electrochemistry. Successfully built and managed large (up to 25 plus head-count) teams of academics and engineers with deep technical capabilities. Current focus is on the National South African Hydrogen Road Map development as well as on PEM water electrolysis, EHC (electrochemical hydrogen compression) and H2 storage in LOHC.	

Name	Feng-Yuan Zhang	
Affiliation	University of Tennessee, USA	
Invited Keynote Lecture		
Presentation Title	**WFCC2021-208: Pathways to highly efficient hydrogen production: manipulating transport and electrochemical reaction with ultralow catalyst loading**	
Abstract (Approximately 200 words)	Proton exchange membrane electrolyzer cells (PEMECs) have received increasing attention for efficient hydrogen/oxygen production and energy storage, even at low-temperature operations. It has been strongly desired to promote catalyst activities and utilizations in PEMECs and to optimize their designs with a better understanding of microscale ultrafast electrochemical reactions and interfacial effects inside PEMECs. A novel titanium thin liquid/gas diffusion layer (LGDL) with well-tunable pore morphologies was developed by employing nano-manufacturing, remarkably reducing the interfacial, ohmic, kinetic, and transport losses in PEMECs. In addition, the LGDL thickness reduction from hundreds of µm for conventional LGDLs to tens of µm leads to a decrease in the weight and volume of the PEMEC stack. More importantly, by taking advantage of the novel LGDL coupled with the development of a transparent PEMEC and a high-speed micro visualization system, the rapid electrochemical reactions and multiphase transport inside PEMECs are revealed to occur only on the catalyst layer adjacent to good electrical conductors. Based on these findings, thinfilm catalyst-coated LGDLs (CCLGDLs) are fabricated and exhibit much higher mass activity and catalyst utilization than conventional catalyst-coated membranes. Furthermore, an innovative electrode design strategy is proposed to build electron/proton transport nanohighways to ensure that the whole electrode meets the triple-phase boundary, therefore significantly enhancing oxygen evolution reactions (OERs) and hydrogen evolution reactions (HERs) and promoting inexpensive and earth-abundant electrocatalysts.	
Biographical Sketch (Approximately 200 words)	Dr. Feng-Yuan Zhang is a Professor and founding director of NanoHELP in the Department of Mechanical, Aerospace and Biomedical Engineering at UT Space Institute, University of Tennessee, Knoxville. Prior to that, he had experience at University of Delaware, Penn State University, the University of California, Los Angeles and Stanford University. He received his B. S. and M.S. from Nanjing University of Aeronautics and Astronautics and received his Ph. D. from Nagoya University. His research interests lie in thermofluid, micro/nanotechnology, energy, multifunctional materials, advanced manufacturing, propulsion, sensors, and state-of-the-art spectroscopies and diagnostics. He has been team leader or investigator for numerous projects on hydrogen production, oxygen generation, water electrolyzers, fuel cells, pulse detonation engines, arcjet thrusters, electrochemical reduction of CO_2/N_2 to high-value products, and advanced instrumentation. His group develops thin and well-tunable liquid/gas diffusion layers (LGDLs) and catalyst-coated LGDLs (CCLGDL) with desired transport, catalytical, electrical and thermal properties, and investigates *in-situ* microscale ultrafast electrochemical reactions, interfacial effects and microfluidics in electrolyzer cells. Multiple conventional parts are integrated into one multifunctional plate to reduce the weight, volume and component quantity. He has authored/co-authored 4 book chapters and over 100 other publications, and has given over 60 talks. More information can be found at http://fzhang.utsi.edu/default.htm.	

Name	Simon Thiele	
Affiliation	Jülich Research Center and Friedrich-Alexander-Universität Erlangen-Nürnberg	
Invited Keynote Lecture		
Presentation Title	**WFCC2021-209: Novel concepts for membrane electrode assemblies in fuel cells and water electrolysers**	
Abstract (Approximately 200 words)	Solid polymer electrolyte membranes are one of the most important electrolyte concepts for both hydrogen fuel cells and water electrolysers. Here, the so far most successful electrolyte membrane type are acidic membranes based on perfluorosulfonic acid with trade names such as Nafion or Aquivion. However, acidic polymer types make the use of noble metals in both fuel cells and water electrolysers necessary, as the acidic environment causes fast degradation of non-noble metals. Recently anion exchange membrane (AEM) polymers are applied for both water electrolysers and fuel cells. These materials in principle make it possible to use non-noble metals such as nickel as catalysts, which is less costly. In AEM water electrolysis it is also possible to use other materials than titanium as porous transport electrode material which again could significantly decrease cost. However, ionic conduction in alkaline is intrinsically worse than acidic conduction and also some electrode reactions such as the hydrogen oxidation are a problem under alkaline conditions. Very recently also bipolar systems which contain alkaline and acidic parts in the membrane electrode assemblies are investigated aiming on taking nothing but the best from the acidic and the alkaline world. In this lecture we give an overview and a critical discussion about recent literature, challenges and opportunities on the novel alkaline and bipolar solid electrolyte membrane concepts for fuel cells and water electrolysers.	
Biographical Sketch (Approximately 200 words)	Prof. Dr.-Ing. Simon Thiele studied physics at the University of Freiburg. In 2009 he started a PhD on the tomographic reconstruction of catalyst layers for proton exchange membrane fuel cells at the Institute of Microsystems Technology of the University of Freiburg which he completed in 2013. From 2011 until 2017 he was group leader of the junior research group 'porous media' at the same institute. Since 2018 he is leader of the Electrocatalytic Interface Engineering research department at the Helmholtz Institute Erlangen-Nürnberg for Renewable Energy consisting of more than 30 PhD students and postdocs in three teams. Also since 2018 he is a professor at the Department of Chemical and Biological Engineering at the technical faculty of the Friedrich-Alexander-University Erlangen-Nürnberg. His research focuses on novel concepts for electrochemical conversion devices such as fuel cells or electrolysers.	

Name	**Nada Zamel**, Patrick Schneider, Anne-Christine Scherzer, Mathias Klingele and Ulf Groos	
Affiliation	Fraunhofer Instiute for Solar Energy Systems ISE, Germany	
Invited Keynote Lecture		
Presentation Title	**WFCC2021-210: Catalyst coated membranes – their structure, their performance and their durability**	
Abstract (Approximately 200 words)	Further development of polymer electrolyte membrane (PEM) fuel cells and their ultimate commercialization rely heavily on the systematic development of its components to meet stability and cost targets. This is especially true for the catalyst coated membrane (CCM) where to-date structuring of its components has led to many breakthroughs. The CCM is the heart of the cell, where the half-cell reactions occur and the byproducts are produced. The various transport phenomena simultaneously taking place in this assembly are complex in nature, resulting in most of the losses in performance. Material design plays an important role in reducing these losses and in prolonging the lifetime of the cell and its components. In this talk, we touch on the design and production of the catalyst coated membrane via screen printing. We will give an overview of our activities on production of catalyst layers with the focus of the talk on the beginning and end of life performance. Effect of ink ingredients, especially those of the cathode catalyst layer, will be discussed in detail. Finally, we look at how machine learning can be used as a tool for the advancement of electrode design and its production.	
Biographical Sketch (Approximately 200 words)	Dr. Nada Zamel is a senior scientist at Fraunhofer Institute for Solar Energy Systems, ISE, in Freiburg, Germany. Her research interests are focused on various topics pertaining to material development and cell characterization of PEM fuel cells. To-date, the projects in which she has been involved vary from life cycle analysis, to investigation of the effect of air and hydrogen contamination on PEM fuel cells, to analyzing the effects of various stressors on the lifetime of PEM fuel cells and to the production of catalyst coated membranes. She is a proud University of Waterloo graduate, having obtained her bachelors, masters and doctoral degrees from there in 2005, 2007 and 2011, respectively.	

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Name	Li Chen	
Affiliation	Xi’an Jiaotong University	
Invited Keynote Lecture		
Presentation Title	**WFCC2021-211: Pore-scale and Multiscale Numerical Study of Physicochemical Processes in PEM Fuel Cell**	
Abstract (Approximately 200 words)	Advanced pore-scale and multi-scale numerical methods have been developed to study the physical-chemical-thermal processes inside PEM fuel cells. Pore-scale models based on the Lattice Boltzmann method (LBM) are proposed to study coupled multiphase flow, heat and mass transfer and electrochemical reaction in gas diffusion layer and catalyst layer. Macroscopic transport properties of the porous electrodes are predicted. Effects of pore structures and surface wettability on liquid water and distributions are studied. Local transport resistance across the pore-ionomer interface in nanoscale catalyst layer is explored. The relationship between structures, transport processes and performance is investigated in detail. Multi-scale numerical method is then developed by upscaling the pore-scale models into cell-scale models. Based on the pore-scale and multiscale studies, structures of the porous electrodes are optimized to alleviate flooding, enhance mass transport and reduce cell cost.	
Biographical Sketch (Approximately 200 words)	Li Chen is a full Professor at Xi’an Jiaotong University (XJTU) China. He obtained his PhD degree in Engineering Thermophysics at XJTU in 2013, followed by a Director Postdoc at Loa Alamos National Lab. His research focuses on transport phenomena in porous media with background of fuel cell, flow battery and hydrocarbon resource exploitation. He has published 72 SCI papers in a variety of top journals, including International Journal of Heat and Mass Transfer, Journal of Power Sources, Langmuir, Nano Energy, International Journal of Hydrogen Energy, Journal of Computational Physics, Physical Review E, Electrochemica Acta, etc. His publications have been cited over 3300 times (Google Scholar), with personal H index at 32. Furthermore, his research has also resulted in over 40 conference presentations (including 6 keynote presentations), 4 patents and 3 software copyrights. He was the winner of Young Scientist Award of Asian Union of Thermal Science and Engineering. He is on the editorial board of international Journal Frontiers in Heat and Mass Transfer.	

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Name	Jeff Gostick	
Affiliation	Department of Chemical Engineering University of Waterloo	
Invited Keynote Lecture		
Presentation Title	**WFCC2021-212: Pore-Scale Modeling of Electrode Processes**	
Abstract (Approximately 200 words)	The physical structure of electrodes plays a decisive role in their performance. Electrodes must be porous due to the necessity of simultaneous pore- and solid-phase transport. Unlike traditional porous materials (i.e. rock and soil) electrodes are manufactured, so their structure can be built to specifications, but the complexity of the physical phenomena occurring within presents a challenging design problem. Modeling the complex multiphysics with pore-scale resolution can provide valuable insights into the interplay between structure and transport limitations, but the computational cost of such models can be unreasonable. Pore network modeling provides an alternative means of capturing pore-scale processes but with a massive reduction in computational cost (1,000x or more). Recent work by our group has focused on building true multiphysics capabilities into a pore network modeling framework, to study electrodes for a variety of electrochemical devices. An overview of the pore network philosophy will be given as well as an explanation of extracting networks from tomographic images. Results from simulations of fuel cell catalyst layers will be presented, including addressing the impact of ionomer distribution and morphology, and the transport of oxygen within.	
Biographical Sketch (Approximately 200 words)	Jeff Gostick is an Associate Professor in Chemical Engineering at the University of Waterloo where he runs the Porous Materials Engineering & Analysis Lab. His research is centered around understanding the structure-performance relationship in electrodes found in hydrogen fuel cell, redox flow systems, zinc-air cells, Li-ion batteries, and super-capacitors. His group uses a combination experimental characterization, novel production methods, and advanced custom computational tools. He is the lead developer of the open source pore network modeling project OpenPNM (openpnm.org), as well a PoreSpy, a tool for porous media image analysis (porespy.org). Prof Gostick is a licensed professional engineer, has published over 70 journal articles, and was recently named an Emerging Leader by the Canadian Society for Chemical Engineering.	

Name	Kui Jiao	
Affiliation	Tianjin University	

Invited Keynote Lecture

Presentation Title	**WFCC2021-213: Artificial intelligence assisted design of next-generation high-power-density proton exchange membrane fuel cell**
Abstract (Approximately 200 words)	Great expectations have been put on the development of proton exchange membrane (PEM) fuel cell for the global energy transition. However, for further commercialization of fuel cell products, such as fuel cell vehicles (FCV), a critical technical hurdle brought by many technical problems is the improvement of PEM fuel cell power density. In this talk, the technical development directions are presented for the design of next-generation PEM fuel cells operating at a goal power density of 6 kW L^{-1} or even higher. An overview of the most advanced techniques is given regarding the modifications of the membrane electrode assembly (MEA) and its components, bipolar plate (BP), and integrated porous BP-MEA design. Some representative ideas among them are specially discussed from the perspective of water and thermal management, material development. In addition, artificial intelligence (AI) has gained increasing attention in material/energy development. In this perspective, this talk also embraces it application and potential in the innovative design of PEM fuel cell and its component. The contribution of physics-informed machine learning on the development of fundamental knowledge and correlations, material improvement, cell optimization, system control, power management, and monitoring of operation health for PEM fuel cells is presented.
Biographical Sketch (Approximately 200 words)	Kui Jiao is currently a professor in the State Key Laboratory of Engines at the Tianjin University, China. He received his Ph.D. degree of mechanical engineering in 2011 from the University of Waterloo, Canada. His research interest includes fuel cell, battery, thermoelectric generator, turbocharger compressor, etc. He has published one book on fuel cell water and thermal management, and 100+ papers in international journals such as Progress in Energy and Combustion Science and Joule. He severed as the Chair for several international conferences such as International Conference on Energy and AI. He was granted the "National Natural Science Foundation of China – Outstanding Youth Foundation" in 2016, and the "UK Royal Society – Advanced Newton Fellowship" in 2018. He has led 30+ national and industrial projects in China, and provided modeling and design services in development of fuel cell engines for many major automotive fuel cell manufactures such as FAW, SAIC Motor, Sunrise Power, Bosch and Weichai Power. He serves as the Editor of Energy and AI and Associate Editor of International Journal of Green Energy. He also serves as the Vice President of Fuel Cell Engine Division, Chinese Society of Internal Combustion Engine (CSICE).

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2021 WORLD FUEL CELL CONFERENCE

AUGUST 16-20, 2021 | WATERLOO, CANADA

Name	Erik Kjeang	
Affiliation	Simon Fraser University	
Invited Keynote Lecture		
Presentation Title	**WFCC2021-214: Fuel Cell Durability Improvements Guided by 4D In-situ X-ray Visualization**	
Abstract (Approximately 200 words)	The global interest in hydrogen fuel cells for heavy duty vehicles is growing rapidly. However, the fuel cell durability requirements for heavy duty bus, rail, and truck applications are three or four times greater than for light duty passenger vehicles, which poses a significant challenge for membrane electrode assembly (MEA) design and integration. Our research addresses this challenge through customized X-ray computed tomography (XCT) visualization of miniaturized fuel cells subjected to accelerated stress testing. Given its non-invasive nature, the XCT methodology enables unique experimental workflows for 4D in-situ visualization by periodic, 3D identical-location imaging of fuel cells as a function of degradation time. Results obtained from post-processed 4D image sets are used to determine the failure mode, root cause of degradation, and other influential factors throughout the progression of a given degradation process. Knowledge gained from such experiments are subsequently used to develop mitigation strategies for durability improvement, which are then demonstrated and evaluated by repeat testing of aptly modified MEA designs. Specific examples will be given for improved mechanical, chemical, and chemo-mechanical membrane durability.	
Biographical Sketch (Approximately 200 words)	Dr. Erik Kjeang is an Associate Professor in Mechatronic Systems Engineering at Simon Fraser University (SFU) in Vancouver, Canada and Canada Research Chair in Fuel Cell Science and Technology Development. Dr. Kjeang obtained a Ph.D. in Mechanical Engineering from the University of Victoria, Canada and an M.Sc. in Energy Engineering from Umea University, Sweden. Prior to joining SFU, Dr. Kjeang worked as a research engineer at Ballard Power Systems. He has 17 years of experience with fuel cell research, focusing on electrode and cell design. Dr. Kjeang is also a recognized expert on fuel cell durability and recently contributed technology for enhancing and predicting membrane lifetime in fuel cell buses in collaboration with Ballard. His lab at SFU features Canada's first facility for multi-length scale X-ray tomography, which is optimal for visualization of electrochemical cells. He has raised more than $20M in funding and authored 120 peer reviewed journal publications and 6 patents.	

International Association for Hydrogen Energy
IAHE Fuel Cell Division
UNIVERSITY OF WATERLOO
CHFCA Clean. Efficient. Energy.
WATERLOO INSTITUTE FOR nanotechnology

Name	Marc Secanell	
Affiliation	University of Alberta, Canada	
Invited Keynote Lecture		
Presentation Title	**WFCC2021-215: Transient, multi-phase analysis of polymer electrolyte fuel cells: Insights from computational modeling at multiple scales and experiments**	
Abstract (Approximately 200 words)	Polymer electrolyte fuel cell (PEFC) vehicles have already met most customer requirements including long range, quick refuelling and start-up at sub-zero temperatures. However, PEFCs are still too expensive for large scale commercialization, and further cost reductions could be achieved by operating at higher current densities at reduced Pt loading. High current density operation results in increased water production that accumulates over time in the porous cell structure, blocking fuel and reactant transport and shutting down the cell. In order to analyze fuel cell architectures and strategies that mitigate accumulation in PEFCs, pore level imaging, analysis and simulation tools to study gas and liquid transport; and, volume-averaged transient PEFC models have been developed in the open-source software OpenFCST (www.openfcst.org). These tools can now be used to predict how water accumulates in varying electrode microstructures, and combined to generate a comprehensive numerical model that accounts for water accumulation over time at multiple spatial scales. This presentation aims at highlighting these recent advances in simulation tools and how, when combined with detailed experimental validation, they can be used to gain insight into the physical processes inside the fuel cell, such as water accumulation in catalyst layer with varying pore size distribution, water dynamics in the membrane, the role of microporous layers on mitigating water accumulation in the electrode, and the effect of H_2 cross-over on reducing the open cell voltage of low loading platinum electrodes.	
Biographical Sketch (Approximately 200 words)	**Marc Secanell** is a Professor at the University of Alberta, Canada. He received his Ph.D. (2008) and M.Sc. (2004) from the University of Victoria, Canada, and B.Eng. (2002) from the Universitat Politècnica de Catalunya (BarcelonaTech). His research interests are in the areas of: a) analysis and computational design of energy systems, such as PEFCs, polymer electrolyzers, flywheels and cooling towers; b) fabrication and characterization of PEFCs and electrolyzers; c) finite element analysis; and, d) multidisciplinary design optimization. His current research projects include the development of the open-source fuel cell simulation toolbox (OpenFCST), an open-source framework for analysis and design of electrochemical energy systems, and the fabrication and characterization of low loading PEFCs and electrolyzers. He has been invited speakers at prestigious conferences such as the Electrochemical Society Meeting and the Gordon Research Conference in Fuel Cells. He is the co-chair of the 2022 GRC Fuel Cell conference.	

Name	Zixi Wang	
Affiliation	**Department of Mechanical Engineering, Tsinghua University, China**	
Invited Keynote Lecture		
Presentation Title	**WFCC2021-216: High performance sealing technology for stack assembly in proton exchange membrane fuel cell (PEMFC)**	
Abstract (Approximately 200 words)	In a proton exchange membrane fuel cell (PEMFC), sealing stability is necessary to the high performance and safety of stack assembly. Reliable sealing also determines the consistency of mechanics, durability, and manufacturability of the fuel cell stack assembly. This study aims to systematically review the current high performance sealing technology, with emphasis on the structural strategy of stacks. A coupled relationship was established to analyze the contact properties of membrane electrode assembly (MEA) and sealing components. In sealing materials, the specific performances, such as, airtightness, permeability, and stress relaxation, were introduced to realize reliable assembly, together with ageing resistance. In the assembly process, several forming processes of sealing components were proposed to optimize the geometrical and material parameters in the industrialization production of PEMFC. A promising development trend in sealing technology for stack assembly was addressed to achieve the much higher performance of PEMFC.	
Biographical Sketch (Approximately 200 words)	Dr. Zixi Wang graduated from Bauman Moscow State Technical University, Russia. Associated Professor at the Department of Mechanical Engineering. Tsinghua University, China. Senior Deputy Director, Institute of Design and Engineering; Director, Joint Research Centre for Plastic Sealing, Tsinghua University, China. His research interests are the failure analysis and reliability design of machinery, sealing technology, structural optimization design, reactor sealing in hydrogen fuel cell, rubber polymer and plastic seals, friction and wear of materials, flow through porous media, hydrogen storage. Most funding supports are from the National Science and Technology Major Projects, National Natural Science Foundation of China, Aviation Funding. Excellent research track record is at the sealing materials, computational fluid dynamics, magnetic suspension bearing, sealing engineering and tribology. He has published more than 50 peer-reviewed papers in top journals, and has 50 authorized invention patents.	

Name	**Yan Xiang**	
Affiliation	Beihang University	
Invited Keynote Lecture		
Presentation Title	**WFCC2021-217: R&D Strategies for Low-cost High Temperature Polymer Electrolyte Membrane Fuel Cell Technology**	
Abstract (Approximately 200 words)	Proton exchange member fuel cells with an operating temperature over 100 ℃ (HT-PEMFCs) own remarkable features, for example, the combined heat and power generation, high tolerance for the impurities, and simplified system design, which all are favorable to the integrated reforming fuel systems. Nevertheless, the commercialization of HT-PEMFC technology has been significantly hindered by the high cost of the fuel cell due to the high loading of Pt in electrodes and the cost of the state-of-the-art high-temperature membranes (HT-PEMs) of polybenzimidazole. Toward the target of developing low-cost HT-PEMFCs, significant efforts have been made to develop novel HT-PEMs, the commercialized membrane electrode assemblies (MEAs), and the fuel cell stack prototypes in our lab. Up to date, a few novel HT-PEMs have been fabricated by several strategies including simple blending, microphase separation, cross-linking and side group grafting, etc. The casting process of PPtec® serial membrane products with a width of 40 cm and continuous length proved the feasibility in scale-up production. Along with the development of low-cost HT-PEMs, the fabrication technology of MEAs has been comprehensively improved by tuning the types and content of the binder, and the fabrication procedures of the catalytic layer, and resulted in significantly reduced cost with remained competitive performance. The MEA shows exceptional durability up to 3000 h under 150 ℃ and a constant load of 0.2 A cm^{-2}. The fuel cell stack prototype with an active area of 165 cm^{2} has been assembled and under long-term stability testing. Currently, the fuel cell stack shows outstanding stability during start-up/shutdown cycles and reaches the peak power output of 1.15 kW at 150℃. Overall, the R&D strategies on low-cost HT-PEMFC technology are going smoothly which convinces the successful transformation of our fundamental research from the core materials design to commercial product and device development.	
Biographical Sketch (Approximately 200 words)	Dr. Yan Xiang is a Professor in Material Chemistry at Beihang University. She serves as the Director of Beijing Key Laboratory of Bioinspired Energy Materials and Devices since 2012. Her research interests focus on advanced materials and devices R&D for sustainable energy conversion, including HT-PEMFC, fluid battery, and bioelectronics and devices. She has published over a hundred research papers among prestigious peer-review journals and serves as principal investigator of many research key projects and international collaborations. Dr. Xiang is a Fellow of the Royal Chemistry Society, UK and Vice Dean of Youth Committee of Chinese Materials Research Society. She is also the board member of The International Academy of Electrochemical Energy Science (IAOEES).	

Name	Jianhua Fang	
Affiliation	Shanghai Jiao Tong University	
Invited Keynote Lecture		
Presentation Title	**WFCC2021-219: Fuel Cell Performances of Sulfonated Multiblock Copolymer Membranes**	
Abstract (Approximately 200 words)	A proton exchange membrane (PEM) is one of the key components of a fuel cell. An ideal PEM must meet the requirements of high proton conductivity, long-term durability, low swelling ratio, high mechanical strength and good barrier properties to fuels and oxygen. In the past two decades a large number of sulfonated hydrocarbon polymers have been extensively studied as potential candidates for fuel cells. However, up to date it still remains a big challenge to develop the PEMs suitable for use in fuel cells operated at elevated temperatures (> 100 °C) and weak humidification conditions (e.g., ⩽ 50%RH). Block copolymerization is an effective method to improve membrane performances. In this presentation, the synthesis, characterizations and fuel cell performances of a series of novel sulfonated multiblock copolyimide membranes will be introduced. Owing to the well-defined nanophase separated morphologies, the block copolyimide membranes generally showed high proton conductivity and good resistance to in-plane swelling. Fuel cell performance of the block copolymer membranes displayed quite weak dependence on external humidification conditions (20-90%RH). High fuel cell performances were achieved at elevated temperatures and low humidities. For example, the H_2-O_2 fuel cell assembled with a block copolyimide membrane showed a high output power density of 1.3 W/cm^2 at 105 °C and 44% relative humidity for both anode and cathode.	
Biographical Sketch (Approximately 200 words)	Dr. Jianhua Fang is an associate professor at the School of Chemistry and Chemical Engineering, Shanghai Jiao Tong University, China. He received his Ph.D. in Materials Science from Yamaguchi University, Japan in 2000. Starting in Apr. 2000, he successively carried out two terms of postdoctoral research at Yamaguchi University (two years) and Case Western Reserve University (one year). Dr. Fang has over twenty years of R&D experience in the development of high performance aromatic polymeric membrane materials (polyimides, polybenzimidazoles, polysulfones, etc.) for various applications such as fuel cells, lithium ion batteries, all vanadium flow batteries, gas separation, pervaporation and microelectronic packing. Up to date, Dr. Fang has co-authored more than 120 publications including over 100 refereed journal papers and five book chapters. He also holds over 30 CN patents and 5 JP patents. Dr. Fang serves as the editorial board member for the international journal *Scientific Reports*.	

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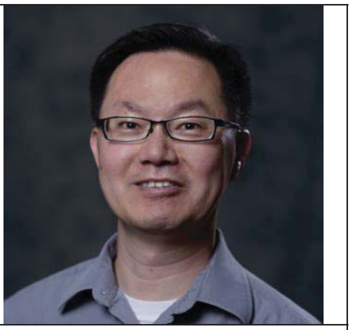
Name	Chulsung Bae, Ford Foundation Professor	
Affiliation	Rensselaer Polytechnic Institute, USA	
Invited Keynote Lecture		
Presentation Title	**WFCC2021-220: Molecular Engineering of Ion-Conducting Polymers for Electrochemical Energy Conversion Technologies**	
Abstract (Approximately 200 words)	Anion exchange membranes (AEMs) based on hydroxide-conducting polymers are a key component for anion-based electrochemical energy technology such as fuel cells, electrolyzers, and advanced batteries. Although these alkaline electrochemical applications offer a promising alternative to acidic proton exchange membrane electrochemical devices, access to alkaline-stable and high-performing polymer electrolyte materials has remained elusive until now. Despite vigorous research of AEM polymer design, examples of high-performance polymers with good alkaline stability at an elevated temperature are uncommon. Traditional aromatic polymers used in AEM applications contain a heteroatomic backbone linkage which is prone to degradation via nucleophilic attack by hydroxide ion. In this presentation, I will highlight recent progress at the Bae group of Rensselaer Polytechnic Institute in the development of advanced hydroxide-conducting polymers and technology transfer effort to commercialize materials for AEM applications. We have developed new synthetic methods that produce polymer design made of all C–C bond backbone and a flexible chain-tethered quaternary ammonium group and that provide an effective solution to the problem of alkaline stability. The advantage of good solvent processability, synthetic versatility, and convenient scalability of the reaction process has generated considerable interest of these polymers, and they are considered leading candidates for commercial standard AEM. AEM fuel cells, electrolyzer, and vanadium redox flow battery tests of some of the developed polymer membranes showed excellent performance, suggesting that this new class of AEMs open a new avenue to electrochemical devices with real-world applications.	
Biographical Sketch (Approximately 200 words)	Chulsung Bae is Ford Foundation Professor at Department of Chemistry & Chemical Biology, Rensselaer Polytechnic Institute. He received BS in Polymer Science & Engineering at Inha University, MS in Materials Science at POSTECH, MS in Chemistry at University of Massachusetts at Lowell, and Ph.D. in Chemistry at University of Southern California under the guidance of Surya Prakash and Nobel Laureate George Olah. He conducted postdoctoral research with John F. Hartwig at Yale University before starting independent academic career in 2004. Bae's research areas focus on development of functional ion-conducting polymers for applications in clean energy technologies.	

Workshop

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2021 WORLD FUEL CELL CONFERENCE

AUGUST 16-20, 2021 | WATERLOO, CANADA

Name	Andrei V. Tchouvelev, PhD	
Affiliation	ISO/TC 197 Hydrogen Technologies, Chair IAHE Hydrogen Safety Division, President A.V. Tchouvelev & Associates, President & CEO	
	Invited Plenary Lecture	
Presentation Title	**Hydrogen Safety Best Practices**	
Abstract	Rapidly emerging hydrogen economy opens a number of new frontiers for hydrogen energy technologies and presents challenges for both safety and standardization caused by the fast paced 4th Industrial Revolution. The focus of this lecture will be to review the broad spectrum of hydrogen safety related topics such as: • Behavior and properties, flammability and combustion; • HP storage, installations, fueling; • Highlight safety and risk concepts and QRA; • Hazardous areas and safety distances, safety standards; • Fuel cell related risks and safety measures/considerations.	
Biographical Sketch	**Dr. Tchouvelev** has over 37 years of experience in the field of hydrogen energy and technology. His professional activities focus on research and consulting in the field of risk management, hydrogen safety and codes & standards. Dr. Tchouvelev serves as the chair of ISO/TC 197 Hydrogen Technologies. He is also President of IAHE Hydrogen Safety Division and a member of the Regulations, Codes & Standards and Safety Working Group of the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE RCSS WG) representing Canada. Dr. Tchouvelev has numerous journal and conference publications on various aspects of hydrogen field including risk-informed approach, risk assessment, safety distances, hazardous areas, CFD modeling and water electrolysis. He recently co-authored a chapter on Regulatory Framework, Safety Aspects and Social Acceptance of Hydrogen Energy Technologies in the book "Science and Engineering of Hydrogen-Based Energy Technologies" (Elsevier, Academic Press, 2018). In June 2018 Dr. Tchouvelev was awarded IAHE Jules Verne Award for his distinguished carrier in hydrogen energy technology including chairing ISO/TC 197.	

Panel Discussion Sessions

Panel Sessions Planned

Panel Topic: **Hydrogen Fuel Cell Technology and Market Trends**

- **Panel Date/Time**: Tuesday, August 17, from 9:20 am – 10:50 am EDT (UTC-4)

Panel Session Description: This panel discussion will focus on the following topics:

- Key hydrogen technology trends in the coming 15 years
- Overview of key market trends: GER / EU, USA / CA, CN, JP
- Role of fuel cell application in mobility
- Importance of regulatory frameworks in key markets

Panel Moderator: Dr. Tobias Christoph Brunner, Hynergy GmbH

Expert Panelists:

- China / Canada: **Dr. Guoyan Hou**, CTO Weichai-Ballard Hy-Energy Technologies Com., Ltd.; Technical Director of Ballard China
- USA: **Dr. Sunita Satyapal**, Director of US DOE EERE's Hydrogen and Fuel Cell Technologies Office
- Europe: **Jorgo Chatzimarkakis**, CEO Hydrogen Europe
- China: **Wang Ju**, Deputy Secretary General Chinese SAE
- Japan: Dr. **Katsuhiko Hirose**, CEO & Chief consultant HyWealth and visiting professor Kyushu University (formerly Toyota)

Biography of Panelists:

Dr. Brunner is a Managing Director and Co-owner of Hynergy GmbH, a Hydrogen Energy and Mobility Engineering company in Germany, as well as of Cryomotive GmbH, a startup company to develop cryogenic hydrogen storage and refueling technology for long-haul commercial vehicles. From 2016 to 2020 he also served Great Wall Motors as their VP Fuel Cell R&D. In 2019 Dr. Brunner was appointed Strategic Council of FTXT Future Energy, the new Hydrogen Fuel Cell Company of the Great Wall Group. Before co-founding Hynergy GmbH in 2015, Dr. Brunner has been serving BMW Group in various roles for more than 10 years, most recently as head of BMW's Technology Project Hydrogen Fuel Cell. Under Dr. Brunner's supervision several fuel cell electric vehicle prototypes and test fleets as well as novel cryogenic storage and refueling technologies have been developed and demonstrated.

Dr. Sunita Satyapal
Director
Hydrogen and Fuel Cell Technologies Office
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

Dr. Sunita Satyapal is the Director for the U.S. Department of Energy's Hydrogen and Fuel Cell Technologies Office within the Office of Energy

Efficiency and Renewable Energy and is responsible for $150 million per year in hydrogen and fuel cell R&D. She has two and a half decades of experience across industry, academia and government, including at United Technologies managing research and business development, and as a visiting professor. She has served as the Chair – is currently the co-Chair – of the International Partnership for Hydrogen and Fuel Cells in the Economy, a partnership among over 20 countries to accelerate progress in hydrogen. She received her Ph.D. from Columbia University and did postdoctoral work in Applied and Engineering Physics at Cornell University.

She has numerous publications, including in Scientific American, 10 patents, and a number of recognitions including a Presidential Rank Award.

Jorgo Chatzimarkakis is the CEO of Hydrogen Europe since August 2021, of which he was the Secretary General since 2016. Before he was Representative of Infineon Technologies in Brussels and Member of the European Parliament (2004 – 2014) inter alia in the ITRE Committee (Industry, Technology, Research and Energy) where he could contribute to lay the cornerstone for the first and the second Joint Undertaking on hydrogen and fuel cells. In 2007 he was elected "MEP of the year" by his colleagues of the European Parliament in the category "Research and Innovation". In 2015 he was appointed ambassador at large for Greece. Mr Chatzimarkakis was born in Duisburg, Germany. He holds German and Greek nationality, a degree in political science from the University of Bonn.

Ju WANG
Deputy Secretary General
China Society of Automotive Engineers

Ju WANG has been Deputy Secretary General of China Society of Automotive Engineers. Ju has a good knowledge on Fuel Cell Vehicle technology development, incentive policy, business models and on developing strong shareholders and stakeholder relationships in China. Having begun her career after her BE (Metallurgical Engineering) in 1992, she was as a trainee engineer in the Anshan Steel Group, the largest iron and steel-making plant in China. Then she worked as a Project Manager in Center of High-tech Development, Ministry of Science and Technology after her graduate degree in 1997. Since she was awarded Master of Management by McGill University in 2002, she has been active in the field of FCV. She has gained expertise based on her hydrogen and FCV demonstration experience during past 13 years. She was project manager of Global Environment Facility/UNDP Demonstration for FCB commercialization in China project from 2003 to March 2017, which was implemented in three phases. The project was the first project to promote FCB and FCV demonstration and application in China, especially project had a good visibility in 2008 Olympic Games Beijing and Shanghai World Expo 2010. She contributed a lot to improvement of local FCV technology, business model research, incentive policy and standards and regulation development etc. Ju has also been holding the positions of Chief Technical Advisor for Hydrogen Economy Demonstration in China as a technical consultant.

Dr. Guoyan Hou is the Technical Director of Ballard China, and CTO of Weichai Ballard Hy-Energy Technologies Com., Ltd., in charge of research, development and manufacturing for fuel cell stacks and modules for heavy duty applications. Before this role, Dr. Guoyan Hou worked as technical director of R&D at SPICHE (The hydrogen company of State Power Investment Cooperation Ltd.), was also the key member of XEV at GWM (the fuel cell section of GWM). Dr. Guoyan Hou had led the effort of planning and implementation of the Hydrogen Test Center in Baoding, China, which has been qualified as a certification organization recently. She is also an active member of Chinese Fuel cell and hydrogen codes and standards development activities. Before working in China, Dr. Guoyan Hou worked at Ballard Power Systems Inc. and AFCC in Vancouver, Canada. Dr. Guoyan Hou received her Ph.D. in Chemical Engineering from Illinois Institute of Technology, the center for electrochemistry excellence, Chicago, IL, U.S.A.

Dr. Prof. Katsuhiko Hirose
CEO & Chief consultant HyWealth Co. and WPI Visiting Professor
International Institute for Carbon Neutral Energy Research (I2CNER)
Kyushu University
Dr. Hirose obtained his MSc degree in Applied Physics, Nagoya University, and PhD degree in Mechanical Science, Kyushu University. Then he worked in Toyota various roles:

1981~ 2019 Toyota Motor Corporation Japan and Belgium (Toyota Motor Europe)

- Advanced engine control, advanced engine development.
- Manager for First hybrid System Prius responsible for fuel economy and emissions.
- Project General Manager, Planner for Hybrid World Deployment
- Project General Manager, Fuel Cell System and Advanced hydrogen storage system development
- Project General Manager, Hydrogen Energy, and Infrastructure development
- 2015-19 Professional Partner, Toyota Motor Corporation

2015-present WPI professor for I2Cner Kyushu University
2017-19 IPCC Lead Author for GHG Guideline refinement
2019 Sep Graduated from Toyota
2019-Oct-present, CEO &Chief Consultant HyWealth CO.

As an engineer always working front line of Toyota engineering for advanced Engine, Hybrid System and Fuel Cell Vehicle. At the same time, working as a planner to develop world strategy of hybrid and fuel vehicle deployment. It is well known as a leader to develop first Hybrid Vehicle Prius for emission and fuel economy. He is also working to initiate several government industries infrastructure program such as German and UK H2Mobility. From 2017, he works for building the world Hydrogen Consortium "Hydrogen Council" as a founding member secretary and as a co-chairman to create several key reports. After graduating Toyota in 2019 he is active as an independent consultant for Hydrogen Energy System and Advanced Mobility. He appears to promote hydrogen in many conferences all over the world. He is currently a member of scientific council of Engie SV, advising several companies including Toyota Motor and Mitsui & CO. Ltd. He is also working as a visiting professor to develop methodologies to implementing environmental technologies into the society in I2CNER Kyushu University.

Expert Discussion Panel

Panel Topic: **Roadmap and R&DD of H_2 and fuel cell around the world**
Panel time and date: 8:00 am - 8:50 am on August 19, 2021 (EDT)

Panel Session Description:

As the world is brought to a standstill by the Covid19, sustainable growth of mankind is becoming an issue of pressing reality, not just theory and prediction. As a pillar in the plans for the recovery from the pandemic, more and more countries are releasing roadmaps for H_2 and fuel cell with ambitious targets. The aim of this panel discussion is to introduce and compare the roadmaps of major countries and regions, so as to examine the differences in strength and stance, identify the issues of common interest, and highlight the challenges needing collaborative action. The status and prospect of research, development, and demonstration of H_2 and fuel cell around the world will also be addressed, with emphasis on the role of fundamental research.

Panel Moderator: Dr. Jianbo Zhang, Tsinghua University, China

Expert Panelists:

- Tobias Brunner, HYNERGY GmbH, Germany
- Ibrahim Dincer, Ontario Tech University, Canada
- Marc Melaina, Hydrogen and Fuel Cell Technologies Office, DOE, US
- Minggao Ouyang, Tsinghua University, China
- Yu Morimoto, Doshisha University, Japan
- Jianbo Zhang, Tsinghua University, China (moderator)

Biography of Panelists:

Tobias Brunner is a Managing Director and Co-owner of Hynergy GmbH, a Hydrogen Energy and Mobility Engineering company in Germany, as well as of Cryomotive GmbH, a startup company to develop cryogenic hydrogen storage and refueling technology for long-haul commercial vehicles. From 2016 to 2020 he also served Great Wall Motors as their VP Fuel Cell R&D. In 2019 Dr. Brunner was appointed Strategic Council of FTXT Future Energy, the new Hydrogen Fuel Cell Company of the Great Wall Group. Before co-founding Hynergy GmbH in 2015, Dr. Brunner has been serving BMW Group in various roles for more than 10 years, most recently as head of BMW’s Technology Project Hydrogen Fuel Cell. Under Dr. Brunner’s supervision several fuel cell electric vehicle prototypes and test fleets as well as novel cryogenic storage and refueling technologies have been developed and demonstrated.

Ibrahim Dincer is a full professor of Mechanical Engineering at Ontario Tech. University (formerly University of Ontario Institute of Technology). Renowned for his pioneering works in the area of sustainable energy technologies he has authored/co-authored numerous books and book chapters, and many refereed journal and conference papers. He has chaired many national and international conferences, symposia, workshops and technical meetings. He has delivered many keynotes and invited lectures. He is an active member of various international scientific organizations and societies, and serves as editor-in-chief, associate editor, regional editor, and editorial board member on various prestigious international journals. He is a recipient of several research, teaching and service awards, including the Premier's research excellence award in Ontario, Canada. During the past seven years he has been recognized by Thomson Reuters as one of the Most Influential Scientific Minds in Engineering and one of the most highly cited researchers.

Marc Melaina is a Senior Analyst at Boston Government Services (BGS) supporting hydrogen systems analysis work within the U.S. Department of Energy’s Hydrogen and Fuel Cell Technologies Office. His areas of expertise include analysis of hydrogen infrastructure and hydrogen energy supply chains, electric vehicle charging infrastructure, zero emission vehicle technologies and markets, and sustainable transportation scenarios. Before joining BGS, he worked for two years at Great Wall Motors and the sister company FTXT Energy Technologies in Boading, China, ten years at the National Renewable Energy Laboratory in Golden, Colorado, and two years at the Institute of Transportation Services at the University of California, Davis in Davis, California. Other work experience includes analysis support for two committees of the National Academy of Sciences and internships at the National Transportation Research Center at Oakridge National Laboratory and the City of Ann Arbor’s Energy Office. Dr. Melaina is a member of the Transportation Research Board’s Committee on Alternative Transportation Fuels and Technologies. He has authored or co-authored 29 technical reports, 14 journal articles, 6 workshop proceedings, 3 book chapters, and over 35 conference papers and presentation proceedings. He has a BA degree in Physics from the University of Utah, and an MS in Civil Engineering and PhD in Natural Resources from the University of Michigan.

Minggao Ouyang, a professor in Tsinghua University, graduated from the Technical University of Denmark with a PhD degree in Engineering in 1993 and is currently the Deputy Director of the Academic Committee of Tsinghua University. He was elected as the Academician of the Chinese Academy of Sciences (Science & Technology Department) in 2017. Prof. Ouyang has been serving as Chief Scientist of Chinese National Research Program of New Energy Vehicles since 2007 and the Director of China-U.S. Clean Energy Research Center - Clean Vehicle Consortium (CERC-CVC) since 2011. He has long been engaged in the research on the advanced powertrain system for vehicles, Recent projects focus on Internal Combustion Engine Control Systems and Hybrid Powertrains, Hydrogen Fuel Cell Engine and Hybrid Powertrains, Lithium-ion Battery Safety and Management. Prof. Ouyang has published 170 peer-reviewed papers on international journals (SCI indexed) and was included in the World’s Highly Cited Researchers 2017. He has been authorized 75 invention patents. Additionally, he won the Second Prize in the National Technology Invention Award in 2007 and 2010, the First Prize in Chinese Automobile Industry Technology Invention Award in 2016, the Prize for Scientific and Technological Achievements from the Ho Leung Ho Lee Foundation in 2008 and IPHE Technical Achievement Award in 2010.

Yu Morimoto is a senior researcher in Doshisha Univ., Kyoto, Japan. Before joining Doshisha Univ., Dr. Morimoto had engaged in the R&D activities in Toyota Central R&D Labs. Inc., for more than 35 years, focusing on the energy-related electrochemistry including PEFCs, secondary batteries and electrolysis. He has published more than 70 peer-reviewed articles and holds 9 US patents. He presented plenty of plenary, keynote and invited talks in various international conferences including WFCC2019 and served as an organizer/chair for various academic meetings such as Gordon Research Conference for Fuel Cells in 2010.

Jianbo Zhang got his PhD degree on Aerodynamics in the University of Tokyo, Japan. He worked in Nissan Research Center on the R&D of fuel cell and LIB during 2000~2011. He was offered the professorship in the Department of Automotive Engineering, Tsinghua University, China, and set up the Lab of Electrochemical Power Sources in 2011. His research interests center around the diagnosis and design of electrochemical devices such as the fuel cell, lithium-ion cell, electrolyzer. He co-authored the book The Theory and Application of the Structure Design for Lithium-Ion Battery. He is a member of the Scientific Committee of International Symposium of Electrochemical Impedance Spectroscopy, and a member of the Scientific Committee of European Fuel Cell Forum.

Expert Discussion Panel

Panel Topic: **The Circular Economy and the Fuel Cell/Hydrogen Industry**

- Panel Date/Time: Friday, August 20, 2021, from 9:50 am – 10:50 am EDT (UTC-4)

Panel Session Description:

The world is running out of resources such as freshwater, fossil fuels, rare earths, and precious metals. Circular economy concepts, including repurposing, reusing, and converting waste into resources, are viewed as a solution. The battery industry has been actively involved with the integration of circular economy concepts. In contrast, fuel cell and water electrolysis industries are critically lagging. Circular economy ramifications extend to education, legislation, and science and engineering. As a result, a diverse panel of experts from academic, governmental, and industrial organizations is selected to sensitize conference attendees and explore and identify avenues to integrate circular economy concepts.

Panel Moderator: Dr. Jean St-Pierre, University of Hawaii

Expert Panelists:

- Dimitrios Papageorgopoulos, United States Department of Energy
- Javier Dufour, IMDEA Energy Institute, Madrid
- Jason Cox, Johnson Matthey, London
- Jean St-Pierre, University of Hawaii

Biography of Panelists:

Dimitrios Papageorgopoulos is the Program Manager for Fuel Cell Technologies in the U.S. Department of Energy's (DOE's) Hydrogen and Fuel Cell Technologies Office, where he oversees efforts focused on the development of fuel cells for transportation, stationary and cross-cutting applications. He has more than 20 years of combined experience in research, technology development and management in areas related to surface science, catalysis, and hydrogen and fuel cell technologies. Prior to joining DOE in 2009, Dimitrios was Head of Catalyst Development at CMR Fuel Cells. Previous positions include those at the Energy Research Centre of the Netherlands (ECN), the FOM Institute for Atomic and Molecular Physics (AMOLF) Amsterdam, and at the Ecole Polytechnique Fédérale de Lausanne (EPFL). Dimitrios is a graduate of the Federal Executive Institute's Leadership for a Democratic Society Program. He received his PhD in Natural Sciences (Chemistry), as a Marie Curie fellow, at the University of Cambridge.

Javier Dufour, Research Professor and Head of the Systems Analysis Unit of IMDEA Energy Institute (Spain). Professor at Rey Juan Carlos University, SMART-E^2 Chair (Spain). Currently, he is Deputy Leader of the Cross-Cutting Activities Technical Committee of Hydrogen Europe Research. Formerly, he was Operating Agent of Task 36 "Life Cycle Sustainability Assessment of Hydrogen Energy Systems" IEA Hydrogen TCP (01/01/15-31/12/17), Chair of the Spanish Network on Life Cycle Assessment -esLCA- (05/11/12-20/06/18) and Vice-chair of Cross-Cutting Research Activities of Hydrogen Europe Research (01/07/16-02/07/20). Currently, his research interests are focused on life cycle sustainability assessment and eco-design of hydrogen systems.

Jason Cox BA, MBA, ACMA
Commercial Director, Fuel Cells, Johnson Matthey
Jason studied at the London School of Economics and Manchester Business School in the UK before training to become a qualified accountant. He has worked for a number of multinational companies in various roles over the last 20 years. The majority have been in the Energy and Chemicals sectors, moving between accounting, project finance, business development, strategy and commercial roles. Most recently he joined Johnson Matthey Plc in 2018, working in their Platinum Group Metals business. In this role he developed their current strategy on the use and recycling of these products and other scarce raw materials linked to growing sustainable technology needs. From this he moved to his current role as Commercial Director for their Fuel Cells business in 2020.

Jean St-Pierre, PhD, PEng, is a graduate of Polytechnique, Montréal, Canada and holds 3 engineering degrees from this institution (PhD, MScA, BIng). More than twenty-five years of his industrial and academic career has been devoted to the development of proton exchange membrane fuel cells including aspects such as water management, freezing, degradation mechanisms, mathematical modeling, diagnosis and measurement methods, electrocatalysis, pure oxygen operation for space and air independent applications, and reactant stream unit operations (gas separation and fuel reforming catalysts). He previously held principal research scientist and research professor positions at respectively Ballard Power Systems (1995-2005), an acknowledged fuel cell manufacturing leader, and the University of South Carolina (2006-2010), formerly the site of the sole National Science Foundation industry/university collaborative research center for fuel cells. He is currently a researcher at the University of Hawaii – Manoa and focuses on fuel cell and related technology activities. His work has led to more than 115 journal papers, book chapters, and conference proceedings, and to more than 30 granted, published, and provisional patents. He is an advisory board member of *Sci* and editorial board member of *Electrochem* and *Molecules*. He is a member of the Electrochemical Society, the International Society of Electrochemistry, the American Association for the Advancement of Science, and Sigma Xi.

Expert Discussion Panel

Panel Topic: **Computational Tools for Polymer Electrolyte Fuel Cell Analysis and Design**

- Panel Time and date: 11:00 am - 12:30 pm on Augutst 20, 2021 (EDT)

Panel Session Description:

Polymer electrolyte fuel cell modeling is a multi-disciplinary problem involving physico-chemical phenomena at multiple spatial and temporal scales. The aim of this panel is to highlight recent advancement in computational modeling of polymer electrolyte fuel cells at stack, cell, pore, molecular and atomistic level, and to discuss the advancements necessary to bridge the gap between scales. Topics of discussion will include how to embed advanced membrane electrode assembly (MEA) models into stack models, how new insights from molecular dynamics (MD) and density functional theory (DFT) can improve current MEA membrane and catalyst degradation models, and how can MEA models harness the computational speed of pore-networks to provide better water management predictions in a reasonable time. Finally, the role of open-source software development, standardization, and its role on improving interaction between scales will be addressed.

Panel Moderator: M. Secanell, University of Alberta, Canada

Expert Panelists:

- S. Beale, Forschungszentrum Jülich, Germany
- M. Eikerling, RWTH Aachen University and Forschungszentrum Jülich (IEK-13), Germany
- Weber, Lawrence Berkeley National Laboratory, USA
- J. Gostick, University of Waterloo, Canada
- M. Secanell, University of Alberta, Canada (moderator)

Biography of Panelists:

Steven B. Beale is a scientist and group leader at Forschungszentrum Jülich. His expertise includes fluid flow, heat/mass transfer, and electrochemistry in fuel cells and electrolyzers, physicochemical hydrodynamics in microstructures and porous media, multi-phase flow, and high-performance computing. Dr. Beale was formerly a principal research officer at the National Research Council of Canada. He has 36 years experience in computational fluid dynamics, and 21 years in fuel cells. He is currently operating agent for the IEA Advanced Fuel Cells, Modelling Annex. He holds engineering degrees from McGill, University of California at Berkeley, and a PhD with Prof. D.B. Spalding FRS, from Imperial College London. An active adjunct Professor at Queen's University since 2003, he is Fellow IMechE (UK) and ASME (USA), from whom he received the dedicated service award. He is currently an editor for J. Electrochemical Energy

Conversion and Storage, Thermopedia, and Computational Thermal Sciences. A former chair ASME Process Industry Division, and former member ASME James Potter thermodynamics medal awards committee, he was also executive director of the CFD society of Canada. Dr. Beale has approx. 150 book chapters, journal articles, peer reviewed conferences proceedings, and technical reports. He has given numerous keynote and invited lectures at LANL, NASA, Imperial College, EU-JSC, ASME, and elsewhere.

Michael Eikerling received his Ph.D. in Physics from Technische Universität München in 1999. From 2003 to 2019, he was Professor of theoretical chemical physics and electrochemical materials science at Simon Fraser University in Burnaby, British Columbia, Canada. Between 2003 and 2013, he held a cross-appointment to the fuel cell institute of Canada's National Research Council in Vancouver, BC, where he shaped a program in physical modeling of fuel cells. As of May 2019, he was appointed as Professor at RWTH Aachen University and Director at the new sub-institute for Theory and Computation of Energy Materials (IEK-13) in Forschungszentrum Jülich, Germany. His research employs a comprehensive spectrum of methods in physical theory and computation. He has made high impact contributions to: transport phenomena at interfaces and in nanopores, theory and computation of electrocatalytic phenomena, self-organization in electrochemical materials, statistical physics of heterogeneous media, porous electrode theory, and modeling and diagnostics of electrochemical devices. Prof. Eikerling has supervised > 60 highly qualified personnel, including 22 PhD students and 25 postdoctoral fellows. He has published over 150 journal articles (h-index 40), 8 book chapters and 1 textbook. He has delivered 160 invited presentations (including 33 keynote and 8 plenary talks, and 65 seminars). In 2017, he was awarded the Alexander Kuznetsov Prize for Theoretical Electrochemistry of the International Society of Electrochemistry, in recognition of his groundbreaking work on modeling polymer electrolyte fuel cells, with an emphasis on water management, transport and electrocatalysis.

Jeff Gostick is an Associate Professor in Chemical Engineering at the University of Waterloo where he runs the Porous Materials Engineering & Analysis Lab. His research is centered around understanding the structure-performance relationship in porous electrodes used in hydrogen fuel cell, redox flow systems, zinc-air cells, Li-ion batteries, and super-capacitors. His group uses a combination of experimental characterization, novel production methods, and advanced custom computational tools. He is the lead developer of the open source pore network modeling project OpenPNM (openpnm.org), as well as PoreSpy, a tool for porous media image analysis (porespy.org). Prof Gostick is a licensed professional engineer, has published over 70 journal articles, and was recently named an Emerging Leader by the Canadian Society for Chemical Engineering.

Adam Z. Weber holds B.S. and M.S. degrees from Tufts University, and a Ph.D. at University of California, Berkeley in chemical engineering under the guidance of John Newman. Dr. Weber is a Senior Scientist and Leader of the Energy-Conversion at Lawrence Berkeley National Laboratory, co-Director of the Million Mile Fuel Cell Truck Consortium and co-Deputy Director of HydroGen consortium. His current research involves understanding and optimizing fuel-cell and electrolyzer performance and lifetime including component and ionomer structure/function studies using advanced modeling and diagnostics, understanding flow batteries for grid-scale energy storage, and analysis of solar-fuel generators and CO_2 reduction. Dr. Weber has coauthored over 170 peer-reviewed articles and 10 book chapters on fuel cells, flow batteries, and related electrochemical devices, developed many widely used models for fuel cells and their components, and has been invited to present his work at various international and national meetings. He is the recipient of a number of awards including a Fulbright scholarship to Australia, a 2012 Presidential Early Career Award for Scientists and Engineers (PECASE), the 2014 Charles W. Tobias Young Investigator Award of the Electrochemical Society, the 2016 Sir William Grove Award from the International Association for Hydrogen Energy, and a 2020R&D100 award for microelectrode development. He is a Fellow of The Electrochemical Society and the International Association of Advanced Materials.

Marc Secanell is a Professor in the Department of Mechanical Engineering at the University of Alberta, Canada, and the director of the Energy Systems Design Laboratory. He received his Ph.D. and M.Sc. in Mechanical Engineering from the University of Victoria, Canada, in 2008 and 2004, respectively. He holds a B.Eng. degree (2002) from the Universitat Politècnica de Catalunya (BarcelonaTech). In 2008, he was an Assistant Research Officer at the National Research Council of Canada, Institute for Fuel Cell Innovation in Vancouver, Canada and in 2015-16 he was a visiting research scholar in the Energy Conversion Division at the

Lawrence Berkeley National Laboratory, US. His research interests are in the areas of: a) analysis and computational design of polymer electrolyte fuel cells and electrolyzers; b) fabrication and characterization of polymer electrolyte fuel cells and electrolyzers; c) finite element analysis; and, d) multidisciplinary design optimization. His current research projects include the development of the open-source Fuel Cell Simulation Toolbox (OpenFCST - www.openfcst.org), an open-source framework to analyze fuel cells. He has authored over 50 journal articles, 30 conference proceedings and two book chapters receiving over 2,500 citations (h-index: 31 in Google Scholar). He has been an invited speaker at prestigious conferences such as the Electrochemical Society Meeting and the Gordon Research Conference in Fuel Cells. He has received several awards including University of Alberta, Faculty of Engineering Teaching and Research Awards (2020 and 2018) and the Association of Professional Engineers and Geoscientists of Alberta (APEGA) Early Accomplishment Award (2013).

Special Sessions

Special Session: Membrane Electrolyte Materials

Session Description:

Proton exchange membrane materials are key components determining PEMFC performance and durability. Topics from membrane components to ionomer materials in catalyst layers, hydrocarbon and PFSA membranes, proton exchange membranes (PEM) and anionic exchange membranes (AEM), membrane stabilization, from synthesis to membrane casting processes, and from R&D to membrane production are welcome in this session.

Session Organizers:

- Zhiqing (Ken) Shi, National Research Council of Canada
- Michael Guiver, Tianjin University
- Yan Yin, Tianjin University

Dr. Ken Shi is a Senior Research Officer in Energy, Mining and Environment Research Centre at National Research Council Canada (NRC). He received his B.Eng. and M.Sc. from the East China University of Chemical Technology, Ph.D. degree from Simon Fraser University. His research career started as early as in 1987 at Shanghai 3F New Materials Co., Ltd. (Shanghai, China) on fluoropolymer synthesis. Joined at NRC in 2002, Dr. Shi has extended his research interest from polymer synthesis into ion exchange membranes for PEM fuel cells, and recently for other clean energy applications such as vanadium redox flow battery (VRFB), CO_2 electrolyzers, and water electrolyzers. As a well-recognized expert in ion exchange membranes with traceable impacts on the Canadian industry, his expertise has been consistently demonstrated through leading a significant number of sizable projects with universities, industries, and governments, nationally and internationally.

Dr. Michael Guiver obtained his BSc (London University) and MSc (Carleton University) in Chemistry, and his PhD in Polymer Chemistry from Carleton University in 1988. He served 12 years as an Editor for the *Journal of Membrane Science* (2009–2020). He previously served on ACS Editorial Boards, and is currently a member on the International Advisory Board of *Macromolecular Research* and on the Editorial Boards of *Polymers* and *Membranes*. He is a Fellow of the Royal Society of Chemistry and an ACS Poly Fellow. He spent most of his career at the National Research Council Canada, and left in 2014 as a principal research officer. In 2009-2013, he was a visiting professor at the Department of Energy Engineering, Hanyang University, Korea. In September 2014, he relocated to Tianjin University, China as a full-time National 1000-plan Foreign Expert Professor. He has published over 250 papers and his primary expertise is in polymer chemistry and design and his research interests are in polymeric membrane gas separations and ion-conducting membranes for fuel cells. He works on PEMs and AEMs, and is also investigating the simple stabilization of hydrocarbon-based membranes, allowing their practical use.

Dr. **Yan Yin** is a professor at the State Key Laboratory of Engines (SKLE), Tianjin University, China. She received her Ph.D. in 2003 from Yamaguchi University, Japan, in the field of Symbiotic Environmental Systems Engineering. Dr. Yin's research interests include fuel cells, advanced membrane materials, renewable energy, gas separation, hydrogen economy, etc. She holds 10+ international patents and has published about 100 papers including articles in Nature Materials, Nature Communications, Energy & Environmental Science, etc., with 3000+ citations and an H-index of 34. She has been one of the Chinese Most Cited Researchers 2019 by Elsevier (2020).

Session Contents:

Invited Keynote Lecture #1:

WFCC2021-220: Molecular Engineering of Ion-Conducting Polymers for Electrochemical Energy Conversion Technologies by Chulsung Bae (Ford Foundation Professor, Rensselaer Polytechnic Institute)

Invited Keynote Lecture #2:

WFCC2021-219: Fuel Cell Performance of Sulfonated Multiblock Copolymer Membranes by Jianhua Fang (Shanghai Jiao Tong University)

Invited Contribution #1:

WFCC2021-111: Improving ion conductivity in anion exchange membranes by utilizing polymers of intrinsic microporosity (PIMS)

Yan Yin[1*], Tong Huang[1,2], Junfeng Zhang[1], Michael D. Guiver[1,2*]

[1]State Key Laboratory of Engines, Tianjin University; [2]School of Chemical Engineering and Technology, Tianjin University; China

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Invited Contribution #2:

WFCC2021-141 Mechanistic and experimental study of the formation of biofunctionalized nanofiber hybrid membrane with enhanced proton conductivity

Guodong Zhao[1,2], Hang Wang[1], Xupin Zhuang[1,2*], Yan Yin[3*]

[1] State Key Laboratory of Separation Membranes and Membrane Processes/ National Center for International Joint Research on Separation Membranes, Tiangong University, Tianjin, China

[2] School of Textile Science and Engineering, Tiangong University, Tianjin, China

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Invited Contribution #3:

WFCC2021-143: Chain conformation-dependent ion conductivity of PEM: a molecular dynamics study

Chenyang Zheng[1], Junfeng Zhang[1], Yan Yin[1*], Xianguo Li[2*]

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[2]20/20 Laboratory for Fuel Cell and Green Energy RD&D, Department of Mechanical and Mechatronics Engineering, University of Waterloo, Waterloo, ON N2L3G1, Canada.

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Invited Contribution #4:

WFCC2021-145: Proton conducting covalent organic framework membranes for hydrogen fuel cell

Li Cao, Chunyang Fan, Hong Wu*, Zhongyi Jiang

School of Chemical Engineering and Technology, Tianjin University, Tianjin, P R China

* e-mail: wuhong@tju.edu.cn

Invited Contribution #5:

WFCC2021-147 Polymer electrolyte membrane with core-shell tin pyrophosphate proton conductor for fuel cells above 200 ºC

Chang Dong[1], Dong Xiao[2], Guangjin Hou[2], Shanfu Lu[1], Yan Xiang[1], Jin Zhang[*1]

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[2]State Key Laboratory of Catalysis, National Laboratory for Clean Energy, 2011-Collaborative Innovation Center of Chemistry for Energy Materials, Dalian Institute of Chemical Physics, Chinese Academy of Sciences, Dalian, China

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Invited Contribution #6:

WFCC2021-149: High density sulfonated carbon nano-onions as an efficient proton conductor for synthesis of nanocomposite membranes with enhanced water retention and durability

Lili Liu[1], Yao Lu[1], Yangyang Pu[1], Na Li[1], Zhaoxia Hu[1*], Shouwen Chen[1*]

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*Corresponding author: Zhaoxia Hu (huzhaoxia@njust.edu.cn); Shouwen Chen (chensw@njust.edu.cn)

Invited Contribution #7:

WFCC2021-123: UNDERSTANDING STRCTURE-TRANSPORT RELATIONSHIP OF ION CONDUCTING POLYMERS

Jessica (Xiaoyan) Luo1*, Ahmet Kusoglu1, and Steven Holdcroft2

1 Energy conversion group, Lawrence Berkeley National Laboratory

2 Department of chemistry, Simon Fraser University

*Corresponding author current address: Ballard power systems

Invited Contribution #8:

WFCC2021-107: TOLERANCE OF MEMBRANE WITH ADDITIVE TO IRON CONTAMINATION IN PEM FUEL CELL

Nana Zhao[1], Zhong Xie[1], Francois Girard[1], and Zhiqing Shi[1*]

[1]Energy, Mining & Environment, National Research Council Canada,
4250 Wesbrook Mall, Vancouver, BC, Canada V6T 1W5

*Zhiqing.Shi@nrc-cnrc.gc.ca

Invited Contribution #9:

WFCC2021-109: PEMION®: FULLY HYDROCARBON PEMFCS FOR HIGH TEMPERATURE EXHIBITING PERFORMANCE AND DURABILITY

Dr. Michael Adamski, Dr. Hsu-Feng Lee, Dr. Benjamin Britton, Dr. Timothy J. Peckham

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Abstracts of Oral Presentations

Proceedings of the 2021 World Fuel Cell Conference
WFCC2021-002
August 16-20, 2021, Waterloo, ON, Canada

Platinum-Oxygen Interaction Evolution of Pt_3Co Nanowires by Mo Doping Enabling Enhanced Oxygen Reduction Reaction Performance

Zhiping Deng[1], Prof. Xiaolei Wang[1*]
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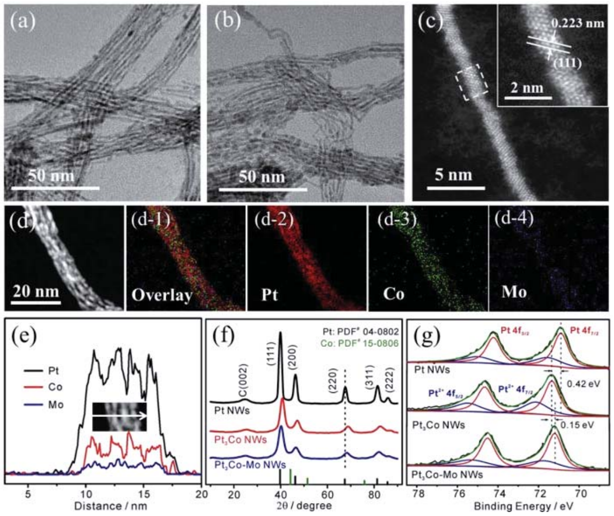
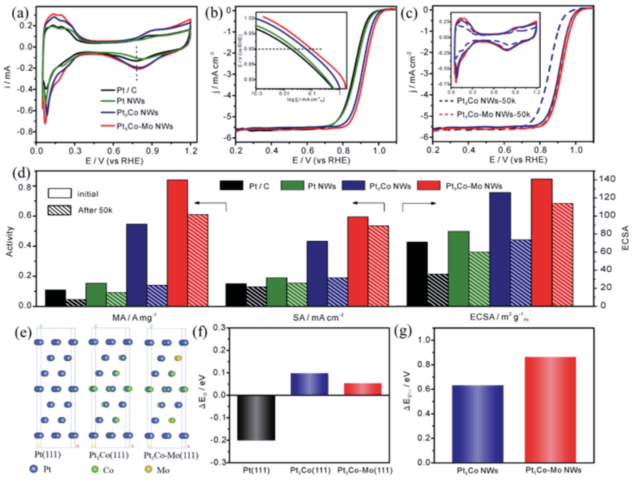
ABSTRACT

The direct conversion of chemical energy stored in hydrogen to electrical energy utilizing proton exchange membrane fuel cells (PEMFCs) is one of the cleanest and most promising ways of power production for next-generation electric transportation. However, the broad deployment and even commercial domination of PEMFCs in the market is still hindered by the high cost and limited lifetime arising from the widely adopted platinum (Pt) based electrocatalysts used to overcome the high overpotential and sluggish kinetics of oxygen reduction reaction (ORR) at the cathode.[2] Challenges remain in the scarcity of Pt and its performance degradation due to agglomeration, detachment, and dissolution of Pt particles as well as corrosion of carbon support, etc. Therefore, substantial performance improvement of Pt-based electrocatalysts is indispensable for efficient Pt utilization, mass activity (MA) enhancement, and durability, which may not be strictly independent of each other.

Herein, we demonstrate a novel strategy of morphology and composition control for both activity and durability, by doping molybdenum (Mo) into ultrafine Pt_3Co nanowires. Such strategy enables the integration of several features favoring high-performance Pt-based electrocatalyst. First, one dimensional (1D) Pt nanostructure, particularly, ultrafine Pt nanowires are less subject to Ostwald ripening, dissolution, and even aggregation than nanoparticles, leading to a much-improved durability. Second, both ultrafine nanowire morphology and controlled growth ensure the exposure of abundant highly active high-index facets, resulting in an enhanced electrocatalytic activity. Third and the most importantly, the Mo doping directly changes the local electronic structure of both element Pt and Co, not only effectively endowing the Pt_3Co electrocatalysts with an enhanced activity but also efficiently preventing element Co from leaching leading to an improved durability. The mechanism analysis and the density function theory (DFT) reveal that Mo doping plays a key role in determining both activity and durability.





Keywords: oxygen reduction reaction, Pt-Co alloy, ultrafine nanowires, Mo doping, long-term durability.

Proceedings of the 2021 World Fuel Cell Conference
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August 16-20, 2021, Waterloo, ON, Canada

Electronic structure studies of graphene and graphene based functional materials by soft X-ray absorption spectroscopy and spectromicroscopy at Canadian Light Source

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ABSTRACT

Deeper understanding of the electronic structure of graphene and the interfaces within graphene-based hybrid materials are crucial for a further enhancement of their applications in fuel cell1. X-ray absorption near-edge structures (XANES) spectroscopy can reveal detailed information on the electronic structure and the local chemistry of the absorbing atom. With soft X-ray, XANES can gain information on the surface with electron yield (probing depth of 5-10 nm) and subsurface with fluorescence yield (probing depth of 100 nm) simultaneously which are perfect to study the surface and interface of materials even under operando. Further, scanning transmission X-ray microscopy (STXM), based on the X-ray absorption process, has a chemical contrast mechanism to allow for imaging at the nano-scale which can nicely correlate performance with structure variation in novel materials2. In this talk I will introduce how to apply soft X-ray XANES and STXM/PEEM at CLS to gain a deeper understanding of electronic structures in graphene and graphene-based hybrid materials. The emphasizes is XANES at C and O K-edge and transition metal L-edge, which can identify the strong chemical bonding nature in graphene supported novel inorganic hybrid nanostructures, the key in making super active non-precious metal fuel cell catalyst.

REFERENCES

[1] Yongye Liang, Yanguang Li, Hailiang Wang, Jigang Zhou, Jian Wang, Tom Regier, Hongjie Dai: Co_3O_4 nanocrystals on graphene as a synergistic catalyst for oxygen reduction reaction. Nature Material 10(10) (2011) 780-7866.

[2] Jian Wang, Jigang Zhou, Yongfeng Hu, Tom Regier: Chemical interaction and imaging of single Co3O4/graphene sheets studied by scanning transmission X-ray microscopy and X-ray absorption spectroscopy. Energy & Environmental Science 6(2013) 926-934.

Proceedings of the 2020 World Fuel Cell Conference
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August 16-20, 2021, Waterloo, ON, Canada

MORPHOLOGY AND MECHANISM OF HIGHLY EFFICIENT N_iF_e LAYERED DOUBLE HYDROXIDE FOR OXYGEN EVOLUTION REACTION

Wulyu Jiang[1,2], Meital Shviro[1, *], Irina Galkina [1,2], Werner Lehnert[1,2], Marcelo Carmo [1,3]
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ABSTRACT

Electrocatalytic water splitting via the oxygen evolution reaction (OER) and the hydrogen evolution reaction is a promising technology for the production of hydrogen from water. However, the kinetic process of OER with the four-electron transfer is inert and therefore considered as a bottleneck. Therefore, the design and development of highly effective electrocatalysts to reduce the energy barrier are urgently needed. Transition metal catalysts have attracted remarkable attention given their abundance in the earth and high performance for alkaline water electrolyzers. In particular, layered double hydroxide (LDH) is a potential species that shows great promise. The NiFe-based LDH has high catalytic activity when the Ni/Fe ratio is adjusted appropriately. To further improve the catalytic activity of NiFe-LDH in OER, the general multilayer LDHs are exfoliated into single layer LDHs. However, how these strategies modulate the structure of LDH and whether there is a synchronous effect on OER stability is still poorly studied.

In this work, we applied a simple precipitation method to tune the composition and size of NiFe-LDH via the synthesis process. The NiFe-LDH with optimized composition and structure exhibit higher activity than most of the known prior literature NiFe-LDH catalysts. The real cell with this catalyst as anode showed lower cell voltage compared at identical current density with that of the typical commercial alkaline water electrolyzer. At the same time, X-ray diffraction, Raman spectroscopy as well as transmission electron microscopy jointly confirmed the composition-dependent geometric size, atomic and electronic structure of the various NiFe-LDHs. The NiFe-LDH with higher Fe content tends to form a monolayer structure, resulting in lower OER activity with higher stability compared to the NiFe-LDH with more nickel. This work provides insights into the relationship between the composition, spatial structure, and electrocatalytic performance of NiFe-LDHs for water splitting and offers a simple and efficient strategy to design promising catalysts for electrolyzers to support the development of the future hydrogen economy.

Keywords: Alkaline water electrolysis, oxygen evolution reaction, layer double hydroxide, composition dependence.

Proceedings of the 2021 World Fuel Cell Conference
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August 16-20, 2021, Waterloo, ON, Canada

PREHEATING HYDROGEN USING VORTEX TUBES FOR IMPROVED COLD START OF HYDROGEN FUEL CELL ELECTRIC VEHICLES

Junior Lagrandeur[1], Arife Uzundurukan[1], Ahmed Mansour[1], Sébastien Poncet[1], Pierre Bénard[2]*
[1]Department of Mechanical Engineering, Université de Sherbrooke, Sherbrooke, Canada
[2]Institut de recherche sur l'hydrogène, Université du Québec à Trois-Rivières, Trois-Rivières, Canada
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ABSTRACT

For fuel cell electric vehicles (FCEV) in cold climates, preventing the water from freezing during the start-up is one of the most crucial factors for a Proton Exchange Membrane Fuel Cell (PEMFC). Therefore, heating is necessary for a safe cold start. However, current methods used for heating in FCEV consume electrical energy in the process. Vortex tube (VT) is a mechanical device that can separate a compressed gas into hot and cold streams without consuming electrical energy and having the advantages of being small, inexpensive, and reliable. The combination of VT and PEMFC can be then a good candidate for FCEV. In this work, 3 different VT designs, combined with an ambient air heat exchanger are proposed to heat the hydrogen (H_2) to improve the cold start capability, and are compared to each other. It uses only the high pressure available in the storage tank to concentrate the enthalpy on one stream. The low enthalpy stream extracts the heat from the ambient. The best overall performance is achieved by using two VTs with a heat exchanger via a real-gas thermodynamic model for 4-passengers 100 kW FCEV even at an ambient temperature as low as -30°C.

Keywords: PEMFC, Ranque-Hilsch vortex tube, cold start, genetic algorithm, throttling loss.

Proceedings of the 2020 World Fuel Cell Conference
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August 16-20, 2021, Waterloo, ON, Canada

INTRODUCTION AND VALIDATION OF A “3D+1D” PROTON EXCHANGE MEMBRANE FUEL CELL MODEL

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ABSTRACT

Nowadays, proton exchange membrane fuel cell (PEMFC) is attracting more and more attention as one of the most promising next-generation energy conversion devices, due to the advantages of high conversion efficiency, de-carbonization operation and decent modularity. Specifically, the application of PEMFC is highly expected to propel the electrification process of transportation tools, which is widely acknowledged as a significant part of energy structure transition for the purpose of establishing environment-friendly society [1]. There are a series of complicated and interrelated physicochemical phenomena occurring during PEMFC operation, including gas diffusion and convection, liquid water transport, membrane water adsorption and desorption, electrochemical reaction, electron and ion conduction, and heat transfer. It is of great importance to shed light on those uncertain or unknown mechanisms to better understand the bottleneck of current technology and provide instructions for future development.

Modeling and simulation have been widely used to investigate the working process of PEMFC [2]. For the perspective of macroscale performance, the computational domain usually considers a complete single cell or a stack with several cells. The difficulty of simulation increases with the complexity of geometry dimension, i.e., one-dimensional (1D), two-dimensional (2D) and three-dimensional (3D). The outstanding advantage of 3D model is the capability to consider the full geometry structure of flow field. On the other hand, it suffers from limited calculation efficiency and unstable convergency. This study is going to introduce a “3D+1D” PEMFC model in order to combine the 3D CFD simulation of flow field and gas diffusion layer (GDL) and 1D description of transport phenomena in microporous layer (MPL), catalyst layer (CL) and proton exchange membrane (PEM). The relevant conservation equations including species, energy, liquid saturation, membrane water and charge potential are solved, involving both the 3D and 1D domain. The mass and momentum conservation equations are solved only in the 3D part. The “3D+1D” model is found to improve the calculation efficiency distinctively compared with the complete 3D model, at the same time maintaining a decent simulation accuracy. A comprehensive model validation is implemented with the simulation results of “3D+1D” model and 3D model under the same parameter set, the experimental data of cell performance and current density distribution at the end of bipolar plate, as well as temperature distribution. The “3D+1D” PEMFC model is expected to expand the range of simulation domain to a higher level, e.g., the commercially-used single cell or short stack, and provide more possibilities for transient simulation, which has been limited to low-dimensional models due to the enormous amount of simulation time.

Keywords: PEMFC, “3D+1D” model, Validation, Simulation time.

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MODIFICATION OF CARBON BLACK FUEL TO IMPROVE THE PERFORMANCE OF A DCFC (DIRECT CARBON FUEL CELL)

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ABSTRACT

A commercial type of carbon black was evaluated as a potential fuel for a direct carbon fuel cell (DCFC). It is believed that carbon black is in the closest form of pure carbon produced by natural gas thermal cracking as proposed here and being studied by numerous research groups. A DCFC converts carbon to a pure carbon dioxide stream suitable for transportation and sequestration, while generating electricity with extremely high efficiency. As received, the use of a commercial carbon black resulted in DCFC performance with a current density of 145 mA/cm^2 and a power density of 105 mW/cm^2 at 850 °C, and 104 mA/cm^2, 51 mW/cm^2 at 750 °C, respectively. By using acid treatment of the commercial carbon black, the performance of the DCFC was improved.

Keywords: direct carbon fuel cell, DCFC, carbon black, acid treatment, power density improvement.

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IMPACTS OF POROUS CARBON SUPPORT MICROSTRUCTURE ON O2 TRANSPORT IN THE CATALYST LAYER OF PEM FUEL CELLS

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ABSTRACT

Global energy consumption and environmental pollution are two significant issues in 21st century. Proton exchange membrane (PEM) fuel cell can directly convert the chemical energy in hydrogen and oxygen to the electrical energy and has many advantages, such as high efficiency, no pollution, low-temperature operation, etc., which is regarded as one of the most promising technologies to solve the two major issues. In the past decade, PEM fuel cell technology has achieved significant development and is successfully commercialized in fuel cell vehicles (FCVs). Toyota launched a FCV (Mirai 2021) with a high volume power density of 4.4 kW L-1. But the power density is still much lower than the target of 9.0 kW L-1 according to the New Energy and Industrial Technology Development Organization (NEDO) of Japan. Moreover, Mirai 2021 sells for up to $49500. Therefore, challenges remain for the cost, power density and durability of PEM fuel cell.

The usage of platinum (Pt) in catalyst layers (CLs) contributes to the major cost of PEM fuel cells. However, reducing the Pt loading will significantly increase the O2 transport resistance in CLs, thus leading to a high voltage loss. The dense ultrathin layer with the tight arrangement of perfluorosulfonic acid (PFSA) chains on the Pt surface results in the major O2 resistance as indicated in our previous research. Furthermore, the adsorption of PFSA on the Pt surface will reduce the Pt catalytic activity. Recently, the accessible porous carbon with high surface area was developed to mitigate the shortfalls. Accessible porous carbon features many micro/mesopores and the Pt nanoparticles inside the carbon particles can be shielded from PFSA chains. Therefore, the O2 transport resistance in CLs will be significantly reduced. In this study, the impacts of porous carbon support on the ionomer structure and O2 transport near the Pt nanoparticles are studied using molecular dynamics simulations.

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EFFECTS OF FLOW CHANNEL OBSTACLE SETTINGS ON THE PERFORMANCE OF PROTON EXCHANGE MEMBRANE FUEL CELL

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ABSTRACT

The novel channel design with obstacles for proton exchange membrane fuel cell is developed in this study. The obstacle shape, position and size were comprehensively investigated based on numerical simulations to provide guidelines for optimal obstacle settings. The results showed that obstacles in the flow channel enhance the mass transfer from the flow channel layer to the catalyst layer, thereby improving the performance of the fuel cell. A cuboid protrusion (length 0.6 mm, width 1 mm, height 0.8 mm) set to the right of the center of the flow channel, is proved to be conducive to forced convection of the fluid. Placing obstacles on the anode alone is more effective than placing obstacles on the cathode alone, and placing obstacles on both electrodes simultaneously. Obstacle blockage ratio in the range of 50% to 75% greatly improves the performance of the fuel cell, which can promote the gas penetration into the diffusion layer without affecting the uniformity of fuel distribution. This article provides a reliable reference for fuel cell flow field design that the performance of the fuel cell could be improved through changing the laminar flow in the flow channel.

Keywords: PEMFC, obstacle, flow channel, numerical simulation, performance.

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ANALYSIS OF THE PURITY OF HYDROGEN AT PUBLIC HYDROGEN REFUELLING STATIONS IN GERMANY

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ABSTRACT

Abundant contaminants in hydrogen are responsible for numerous degradation modes within the fuel cell. In particular, for proton exchange membrane (PEM) based fuel cells for mobile applications a strong impact of contaminations on the long-term stability and thereby performance is well-known. Although these influences have been intensively studied, predominantly the purity of the hydrogen provided at public hydrogen refuelling stations (HRS) is rarely analyzed. To avoid damaging processes initiated by harmful compounds, international standards for the quality of hydrogen set precise limits for contaminations present in hydrogen [1, 2]. Whereas single pathways of contamination, e.g. the synthesis route, have been individually studied in detail elsewhere [3], the provision of hydrogen with different storage processes, as well as transport and compression at the HRS are considered in these investigations as a holistic system.

For the investigation of hydrogen at HRS and the analysis of contaminations in the parts per billion (ppb) range, only a couple of mobile devices for the sampling at 70 MPa exist since no conventional gas cylinder can be used. Moreover, there are no general protocols available for the contamination-free sampling of hydrogen. In this study, a specially designed mobile composite high-pressure hydrogen tank similar to that in fuel cell vehicles is used. With this tank, it is possible to use the standardized dispenser at public HRS with up to 70 MPa. To ensure that the fuelled hydrogen and the subsequent analyses of the contaminants are referable to the so-sampled hydrogen, a specifically developed method is applied. In that regard, the first kilogram of hydrogen is fuelled to purge the system and subsequently, the tank is on-site carefully emptied again following mandatory safety regulations. Finally, the module is refuelled with the amount of hydrogen necessary for the laboratory analysis. By this, contaminants like water and sulphur compounds will be removed from within the module and sampling lines [4]. For investigating the purity of hydrogen, a high-performance gas analyzer based on an ion-molecule reaction mass spectrometer (IMR-MS) is employed.

With this state-of-the-art equipment, i.e. the mobile hydrogen tank and the capable gas analysis, selected HRS in Germany were approached, hydrogen was sampled, and finally analysed for contaminants in the laboratory. Some HRS are supplied with hydrogen from steam reforming of natural gas via delivery by trailer; others produce the hydrogen directly at the refuelling station by on-site electrolysis without the necessary use of trailers. Thus, by investigating the hydrogen with the gas analysis in the laboratory a dependency of the manufacturing processes on the purity can be shown. In the first approach series, HRS supplied by on-site electrolysis showed high purity as expected, in general, but also noteworthy contamination above the threshold of ISO 14687 [1] in the form of water (19.3 ppm), carbon dioxide (2.9 ppm), and nitrogen (751.8 ppm). With this study, it can be estimated whether the dispensed hydrogen at HRS meets the purity requirements of fuel cells for mobile applications specified in ISO 14687 [1].

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Keywords: Contamination, Hydrogen Refuelling Station, Purity Analysis, Hydrogen Sampling, Mass Spectrometer

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Development of a tubular PEM fuel cell

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ABSTRACT

With the increasing energy demand, proton exchange membrane fuel cells (PEMFCs) have gained energy researchers' attention as one of the promising clean power-generating technologies. These technologies provide high energy density, high efficiency, and zero greenhouse gas emission. However, they require dealing with some challenges, including the components' high cost, nonuniform gas distribution, and water removal in the catalyst layers. Considering associated challenges with the current fuel cell design, this paper addresses an alternative tubular structure of the catalyst support and proton exchange fuel cell that can lead to more compact configuration, reduced mass transport losses, and cost and weight reduction. The study involves synthesizing carbon nanofiber-supported Pt electrocatalysts, optimizing Pt loading and morphology, and experimental studies on the novel proposed fuel cell geometry.

Keywords: Tubular, fuel cells, catalyst

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The Effect of Ion Clean, Deposition Power and Au Thickness on the Corrosion Resistance, Conductivity and Throughput Production Rates of Nano-Multilayer Ti/Au Coated SS316 Bipolar Plate for PEFCs

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Low corrosion resistance and high interfacial contact resistance are the main challenges limiting the wide industrialization of stainless steel as bipolar plates material in Polymer Electrolyte Fuel Cells (PEFCs). Conductive, protective coatings should be applied on the surface of stainless steel bipolar plates to prevent thick oxide formation and corrosion while enhance electrical conductivity. In the current work, Nano-multi-layered PVD coatings based on Ti and Au were deposited on SS316L substrate. The aim of this study is to investigate the effect of Au coating thickness and PVD process scale up on the corrosion resistance and interfacial contact resistance properties of SS316. Therefore, Au coating layer was deposited with different thicknesses by controlling the PVD deposition time. Moreover, in order to scale up the coating production, stainless steel surface was cleaned prior to coating using a more time-efficient in-situ cleaning linear ion source and the PVD deposition process was performed with a higher power magnetron to further shorten the coating time. The coatings were characterised using SEM, EDX and XRD, and assessed ex-situ for ICR and corrosion resistance and in-situ for the coating performance and durability under an accelerated stress test protocol.

All coated SS316L revealed significantly low interfacial contact resistance (ICR) values of between 1 and 2 mΩ cm^2. The ex-situ potentiostatic tests of Ti/Au bilayer coatings revealed excellent corrosion resistance in cathodic PEFC environment (0.9 V and 1 mM H_2SO_4) and the corrosion current densities decreased with the increasing of the outer Au thickness. All samples had corrosion current below 165 nA/cm^2. In addition, the corrosion resistance and ICR of the samples cleaned by the new ion cleaning method, and high power magnetron were comparable to those of same thickness coating processed with the conventional coating process. Selected samples were also tested in-situ and showed that the coatings experienced relatively low degradation during the 5-day AST in-situ tests. Extensive scanning electron microscopy (SEM) and X-ray diffraction (XRD) studies showed that the Au coatings covered the SS316L surface homogeneously and maintained physical properties after the ex-situ and in-situ corrosion tests.

Keywords: Stainless steel, PVD, Nano-multilayer Ti/Au, corrosion, AST.

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Power Performance and Degradation of Gold alloyed Platinum-silver Nanorod Array Electrodes in H_2/Air PEMFCs

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ABSTRACT

Single-crystal one-dimensional (1D) catalyst nanostructures such as nanowires and nanorods (NRs) attract lots of attention for overcoming the deficiency of nanoparticle catalysts in PEMFC applications. However, a facile production of 1D Pt-alloy nanostructures is highly challenging due to the requirements of templates or capping agents with conventional preparation approaches, limiting most them to pure material research and few have been demonstrated for practical electrodes in PEMFCs.[1,2]

With a facile formic acid reduction process, based on the size control role and shape inducing effect of Pt, single-crystal PtAg nanorods along the <111> direction are grown on carbon support (PtAg NR/C).[3] Due to the superiority of 1D metal nanostructures and the high electrical conductivity of Ag, with PtAg NR/C as the oxygen reduction reaction catalysts in the cathode, an enhanced power density is demonstrated in the membrane electrode assembly (MEA) test than those of Pt/C and Pt NR/C. However, the dissolution of Ag cannot be avoided during the accelerated degradatioin test (ADT), and they redeposit at the interface between the cathode and polymer electrolyte membrane thus inducing a huge performance drop.

Au is then introduced to tune the atomic arrangement and minimize the atomic segregation of AgPt nanorods to improve the stability.[4] The MEA test with Au–AgPt NR/C as the cathode catalyst shows 1.2-fold higher fuel cell power density than that of Pt/C catalysts, and a lower decline rate of 39.63% compared with 44.19% after an accelerated degradation test (Figure 1). The optimized process is then used to grow Au–AgPt NR arrays directly on gas diffusion layers to fabricate Au–AgPt NR gas diffusion electrodes (GDEs). The removal of carbon support further boosts the electrode stability in the MEA test, recording a 14% lower ECSA loss with the presence of 2 at% Au during the ADT. However, a slightly lower power performance is recorded for the Au–AgPt NR GDE compared with the Au–AgPt NR/C GDE, indicating different catalyst behavior within the operating electrode and a further process optimization is required.

Keywords: PEMFC, Oxygen reduction reaction (ORR), Nanowire, Alloy, Array

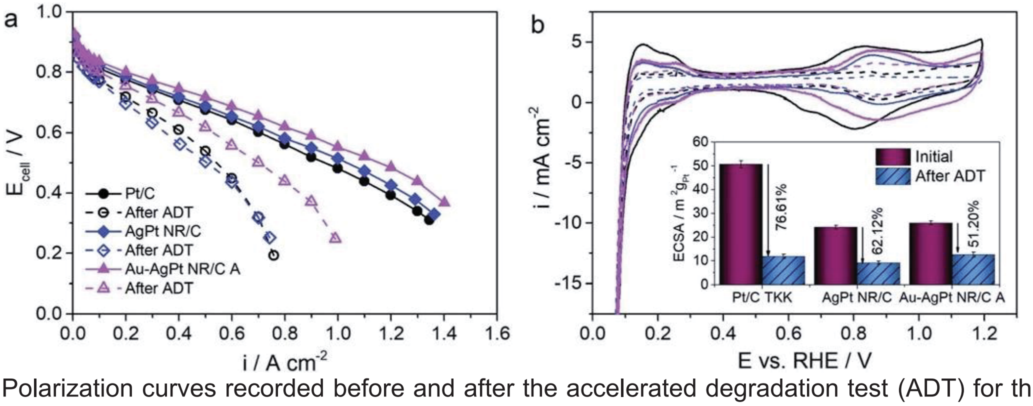

Figure 1. (a) Polarization curves recorded before and after the accelerated degradation test (ADT) for the MEAs with the cathode catalyst made of AgPt/C NR and Au–AgPt NR/C A in comparison to commercial Pt/C (MEA 16 cm^2, Nafion 212, 80 °C, fully humidified H_2/air, 2.5/2.3 bar$_{abs}$, 1.3/1.5). (b) Comparison of cathode CV plots before and after the ADT with the corresponding ECSA decline ratio (inset). The ADT was performed using potential sweeping between 0.6 and 1.2 V at a scan rate of 100 mV s^{-1} for 5000 cycles with H_2/N_2.

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EFFECT OF CNTS SUPPORT IN CL OF PEMFC ON THE STRUCTURE OF IONOMER ULTRA-THIN FILM

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ABSTRACT

Proton Exchange Membrane Fuel Cell (PEMFC)is an energy converter with high power density. However, there are still several problems that hinder the performance improvement of PEMFC. Among them, the ionomer film in the catalyst layer (CL)and around the catalyst constitute a multi-phase nano-scale structure, which is essential for the transportation of protons and water, and is also necessary to the improvement of the utilization rate of the catalyst. In order to improve the material transport capacity of protons and water, a classic molecular dynamics simulation was conducted to established the model of platinum particles on carbon nanotubes (CNTs), which explored: 1) the influence of CNTs on the self-assembly process of ionomer on its surface, 2) the influence of the presence of nano-platinum particles on the structure of the ionomer film around the CNTs. These results provide a molecular basis for the study on the nanostructures inside the CL, and give the way in which the CNTs affect the ionomer film structure.

Keywords: PEM fuel cell, catalyst layer, CNTs, ionomer film, three-phase interface.

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A COMPARATIVE WELL-TO-PUMP ENERGY, ENVIRONMENTAL AND ECONOMICAL (3E) ASSESSMENT OF METHANOL AND HYDROGEN AS ALTERNATIVE FUELS FOR VEHICLES

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ABSTRACT

With the continuous consumption of global fossil fuels, energy crisis and environmental pollutions play crucial roles on the human survival and long-term development. Methanol and hydrogen have been considered as the potential renewable alternatives to fossil fuels. The pathways of reasonably deploying the implementation strategy of methanol and hydrogen economy in the energy transition is directly associated with development of human society. Herein, a comprehensive comparative well-to-pump (WTP) 3E assessment for various methanol and hydrogen production pathways is conducted based on the GREET® software and China data. It considers the information of energy use and efficiency, direct emissions and midpoint environmental impact indicators as well as fuel cost. The gaseous and liquid hydrogen production pathways include coal gasification (CGT), coal coking (CCT), natural gas reforming and electrolysis of alkaline water from renewable and grid electricity, while methanol production includes CGT, CCT and CO_2 hydrogenation. During the CO_2 hydrogenation methanol production process, CO_2 is captured from thermal plant flue gas, biomass gasification and atmosphere, and hydrogen is derived from water electrolysis by surplus renewable and grid electricity. The overall normalized midpoint environmental impacts and energy efficiencies results indicate CCT as well as wind and hydro energy-assisted CO_2 hydrogenation methanol production pathways exhibit the promoted performance compared with conventional hydrogen production pathways. However, compared with the corresponding renewable electrolytic water to hydrogen pathways, the thermal plant flue gas and atmosphere-based CO_2 hydrogenation methanol production pathways exhibit sluggish performance. The economic analysis results illustrate that the overall cost of conventional methanol production pathways are reduced compared with conventional hydrogen production pathways. Specifically, the cost of CCT methanol production pathway is estimated to be 0.025 $/MJ, which is basically equal to the price of gasoline. Besides compared with the corresponding electrolytic water to hydrogen pathways, CO_2 hydrogenation methanol production pathways exhibit a higher economic efficiency. Nevertheless, it still needs a long journey for commercialization. The 3E performances of CO_2 hydrogenation methanol production pathways demonstrate that hydro is superior to wind and solar, and biomass is superior to atmosphere and thermal plant flue gas. Therefore, in the case of methanol production, it is recommended to commercialize CCT in short term and enhance the transformation of methanol infrastructure to create a pre-methanol economic environment. In order to achieve the medium-long-term goal of “carbon neutral” and establish a post-methanol economy, it is recommended to promote the research and development of renewable methanol production technologies with more room for improvement. The research of renewable methanol production technologies can be focused on two aspects: one is to improve the integration and efficiency of CO_2 hydrogenation system by reducing energy consumption per unit of CO_2 captured and hydrogen produced by electrolysis. The other one is to reduce upstream and downstream emissions and costs of renewable power generation devices, especially solar and wind. Compared with methanol pathways, the storage and transportation cost retards the development of hydrogen pathways. In the study, it is recommended to develop hydrogen as a long-term goal, focusing on the storage and transportation promotion at present.

Keywords: Well-to-pump, 3E assessment, methanol, hydrogen.

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EFFECT OF FLOW CONFIGURATION ON GAS BUBBLE DISTRIBUTION AND CELL PERFORMANCE FOR A MICROFLUIDIC FUEL CELL WITH FLOW-THROUGH POROUS ELECTRODES

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ABSTRACT

Microfluidic fuel cells (MFCs) with flow-through porous electrodes produce gas bubbles at the anode, which cover the catalyst surface, break the co-laminar flow interface, and increase ionic transfer resistance between anode and cathode. In this work, a feasible approach is proposed to actively and effectively optimize the gas bubble distribution and reduce their influence on the cell performance. Different from the flow configuration in the conventional MFCs with flow-through electrodes, the reactants solution flow from the microchannel between anode and cathode to the external channel through porous electrodes. The gas distribution during discharging at a constant current density was visualized by a camera. After optimizing the flow configuration, the nucleation and distribution of gas bubbles are changed from the anode surface near the cathode to that away from the cathode, giving rise to the decrease in ionic transfer resistance between anode and cathode. And the forces on the bubbles are also changed, resulting in the bubble quick detachment and further leading to the improvement of fuel transfer from the bulk solution to anode surface. Compared with the MFC with conventional flow configuration (MFC-C), the maximum power density and the limiting current density of the MFC with new configuration (MFC-N) is increased by 66.9% and 84.4%, respectively. And the ohmic resistance of the MFC-C after 5 min discharge is 14.4 Ω, 73.5% higher than that of MFC-N. Moreover, the MFC-N achieves a more stable voltage during the whole discharge time of 20 min. In order to further speed up the bubble removal timely, a porous and hydrophobic PTFE membrane was added for the MFC-N. Gases could be effectively expelled from the porous membrane and few bubbles appear in the main channel in the MFC-N with porous membrane during discharging for 20 min, giving rise to the enhancement of the operation stability and the limiting current density. The proposed approach provided a good and effective way for gas management as well as performance improvement in the microfluidic fuel cell with flow-through porous electrodes.

Keywords: microfluidic fuel cell, porous electrode, flow configuration, bubble distribution, performance.

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Comparison of PEMFCs Based on Pt/C and Pt Nanowire Cathodes by Orthogonal Design Experiments

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ABSTRACT

As one of the most efficient electrochemical energy conversion devices, proton exchange membrane fuel cells (PEMFCs) have attracted plenty of attention. To improve PEMFC power performance, electrodes based on Pt nanowire (NW) arrays have been reported by many groups due to the excellent stability of Pt NWs and the enhanced oxygen transfer characteristics with ordered nanowire arrays[1, 2]. In this study, a four-factor (backpressure, relative humidity (RH), temperature and cathode stoichiometry) and five-level orthogonal experiment is demonstrated to compare their influence on the performance of the membrane electrode assemblies (MEAs) based on Pt/C nanoparticle and Pt nanowire (NW) gas diffusion electrodes (GDEs) as cathodes. Range analysis combined with variance analysis suggests that the backpressure is the most influential factor and exhibits a positive correlation with the power density within the backpressure range of 0-2 bars for both GDEs. Meanwhile, the peak power densities of both GDEs are least influenced by the cathode stoichiometry. However, the RH can affect more on the power density than the temperature for the Pt NW GDE because of the thin catalyst layer, whereas the behavior for the Pt/C is the opposite[3, 4]. The results also show that with the increasing operating temperature above 80°C, the power density decline of the Pt NW GDE is less than that of Pt/C. This indicates a potential for the Pt NW GDE to help keep the humidity of the membrane thus a possibility for application in intermediate temperature PEMFCs.

Keywords: PEMFC, Orthogonal design, Nanowire, Electrode.

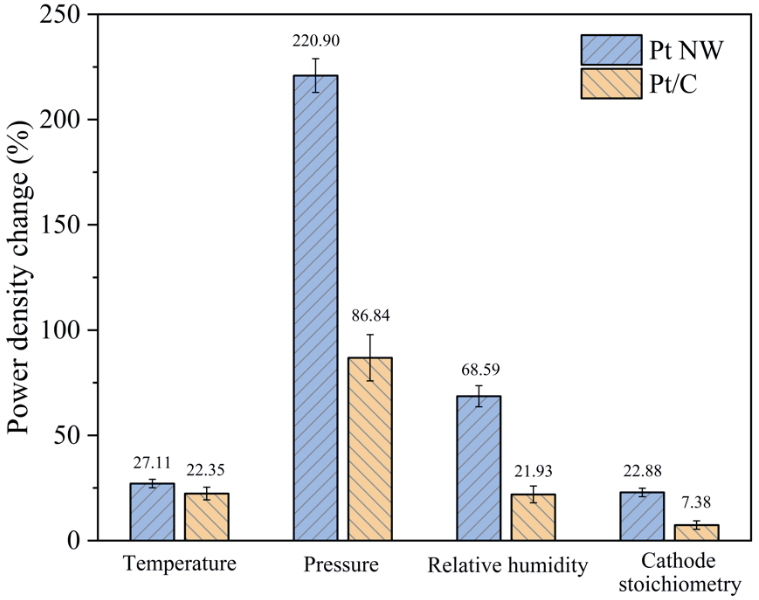

Fig. 1 Power density changes against different parameters for the MEAs based on the Pt/C and Pt NW cathodes. (The power density change is calculated based on the highest and the lowest peak power densities under different parameters. MEA active area: 16 cm^2, Temperature: 50-90°C, H_2/air: backpressure: 0-2 bars, relative humidity: 20-100% and anode/cathode stoichiometry: 1.3/1.3-2.5.)

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PVD coated aluminium bipolar plates for use in lightweight Polymer Electrolyte fuel cell stacks

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ABSTRACT

Metallic bipolar plates are capable of overcoming many of the downfalls faced by conventional graphite bipolar plates such as fragility and machinability. Stainless steel has emerged as the new convention for transport applications. Metallic PVD coated stainless steel can achieve the <1 μA cm^{-2} corrosion current and <10 mΩ cm^2 contact resistance properties set out by the DoE [1]. For applications such as aerospace, and some automotive applications, gravimetric power density is critical and as such stacks should be as light as possible. Stainless steel bipolar plates account for around 70% of the stacks mass. For fuel cells to be employed in such applications as the main power source a lightweight alternative needs to be found.

Aluminium has a density of around 2.7 gcm^{-3} which is 34% of that for stainless steel (stainless steel has a high density of 8 gcm^{-3} [2]. It is also more easily machined and stamped than stainless steel due to its reduced hardness. This makes Al a possible candidate for metallic bipolar plates in light weight stacks [3]. However aluminium corrodes in the fuel cell environment, according to the pourbaix diagram the low pH's (pH 3), high transient potentials in excess of around 0.8V [4] puts aluminium in a state of corrosion. This means that aluminium too will need coating.

To this end, a range of PVD coatings, TiAu, TiC, TiN and CrC, were investigated for their electrochemical corrosion resistance and interfacial contact resistance (ICR) properties. The physical properties of the coatings were analysed using SEM, XRD and Raman before and after corrosion. Finally, the best performing samples were tested in-situ under accelerated stress protocol to assess both their performance and lifetime. The samples have shown excellent ICR values in the region of 2 mΩ.cm^2 however suffered very high corrosion current values in the ex-situ testing. However, TiAu have shown low degradation rate under the AST test. More work is being carried out to improve the corrosion resistance of the coated Al substrates and bipolar plates.

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Keywords: Aluminium, PVD, Bipolar plate.

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MOLECULAR DYNAMICS SIMULATION ON THE CONDUCTIVE AND MECHANICAL PERFORMANCE OF ADVANCED AROMATIC ELECTROLYTES IN PEMFC

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ABSTRACT

New advanced aromatic electrolytes have aroused great concern for their high ion exchange capacity (IEC), anti-decomposition at high temperature, and good mechanical property. So they are the ideal substitute for the polymer Nafion as the ion exchange membrane and catalyst ionomer in the proton exchange membrane fuel cells (PEMFCs). Though many works have been reported of their successful synthesis and good application in the membrane electrode assembly (MEA), micro-modeling and simulation are relatively inadequate. In this work, molecular models are built containing three types of aromatic polymers and the typical Nafion213 structure: sulfonated poly-ether-ether-ketone (SPEEK), polysulfone-phenol-F (psfPAE-F), and phosphoric-pyridine-polyethers (PPP). After molecular dynamics simulation, the proton and oxygen diffusion coefficients are calculated to evaluate the proton-conductive capacity and oxygen-resistant property. The mechanical performance can be estimated by the stress-stain curve. And the interfacial adsorption characteristics are also studied to get a more accurate reactants transfer resistance. The results demonstrate some better conductive and mechanical properties of these poly aromatic electrolytes compared to Nafion. In general, these simulation works are meaningful to have a deeper understanding about the mechanism of the electrolytes' good performance and provide guidance when designing new structures with various chemical groups.

Keywords: molecular dynamics, aromatic electrolytes, IEC, conductive, mechanical, PEMFC

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Controlled Growth of Pd catalysts on Gas Diffusion Layer for Direct Formic Acid Fuel Cells

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ABSTRACT

The excellent performance and safety of direct formic acid fuel cells (DFAFC) promote them as a potential excellent power source for portable electronic devices. However, the real application of the DFAFC is still highly challenging because of poor power performance and cannot compete with the latest Li-ion batteries. Recently, a number of studies have been reported with highly active catalysts and enhanced poisoning tolerance, but most of them focused on only material synthesis and half-cell electrochemical measurement [1]. In this work, a modified formic acid reduction method is proposed [2]. Using this facile template- and surfactant-free self-growth assisted reduction method at room temperature, ultrathin Pd catalysts are uniformly grown on gas diffusion layer (GDL) support through a finely controlled ion reduction process tuning the nucleation and crystal growth. By precisely controlling the reaction speed, Pd catalysts with various nanostructures are achieved. Electrochemical surface area (ECSA) and formic acid oxidation catalytic activity are evaluated using both gas diffusion electrode (GDE) and membrane electrode assembly (MEA) test. Both enhanced mass activity and power performance are successfully demonstrated for the Pd catalyst electrode compared with commercial Pd nanoparticles (Pd/C) (Figure 1).

Keywords: Direct formic acid fuel cell, Gas diffusion electrode, Pd, elelctrocatalyst

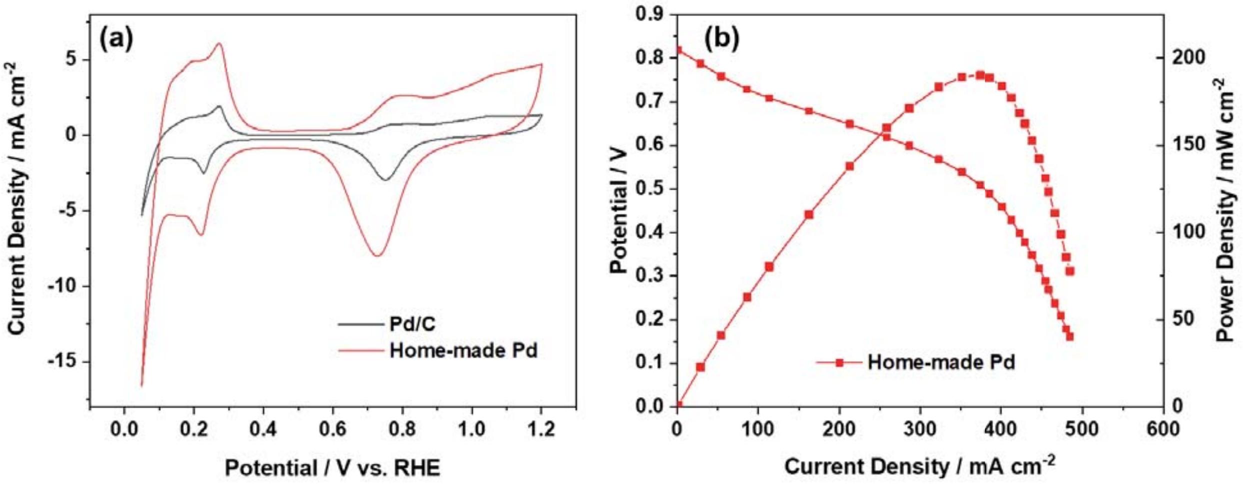

Figure 1. (a) Comparison of cyclic voltammetry curves for the commercial Pd/C and home-made Pd GDE by the ex-situ GDE measurement in the 1.0 M $HClO_4$ aqueous electrolyte; (b) Polarisation and power density curves of the MEA based on the home-made Pd GDE. Test conditions: cell temperature 75 °C, anode: the home-made Pd GDE, 1.0 mg_{Pd}/cm^2, 3 M formic acid at a flow rate of 1 mL/min; cathode: Pt/C catalyst, 2.0 mg_{Pt}/cm^2, dry air at a flow rate of 300 mL/min without backpressure.

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ADDITIVE MANUFACTURING FOR BIPOLAR PLATES IN PROTON EXCHANGE MEMBRANE FUEL CELLS

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ABSTRACT

Proton exchange membrane fuel cells (PEMFCs) are an excellent renewable energy alternative to the modern-day transportation applications. Crucial components of these fuel cells are bipolar plates (BPPs). BPPs are responsible for transporting reactant gases, carrying the current from the membrane electrode assembly (MEA) to the end plates, providing heat and water management, and separating the individual cells. Although these plates are one of the most important parts of the fuel cell, they also make up 80% of the fuel cell’s weight, 50% of its volume, and 40% of its cost; BPPs pose challenges to the commercialization of PEMFCs. To improve these disadvantages and innovate bipolar plate technology, it is highly important to advance current prototyping methods. Traditional manufacturing methods such as stamping, hydroforming, compression molding, and injection molding are often not suitable options for low-cost prototyping and are limited in terms of materials and design abilities. Additive manufacturing (AM) serves as a viable solution to these limitations. It allows for the fabrication of far more complex parts due to the virtual absence of geometric constraints and the ability to save time and money by eliminating the waiting period and manual labor costs associated with tooling. This study evaluates the ability of AM to successfully fabricate a plate that is comparable to traditionally manufactured plates through materials characterization techniques and fuel cell testing.

Keywords: Proton exchange membrane fuel cells, renewable energy, bipolar plates, additive manufacturing, prototyping, conventional manufacturing, materials characterization, fuel cell testing

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UNDERSTANDING OF THE EFFECT OF PORE-FORMING ON OXYGEN TRANSPORT BEHAVIOR IN ULTRA-LOW PT PEMFCS

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ABSTRACT

The issue of cost remains the primary challenge to commercialization of polymer electrolyte membrane fuel cells (PEMFCs) vehicles and must be well addressed. It is acknowledged that the Pt loading used in PEMFCs should be lowered to an ultra-low level of 0.1 g_{Pt} kW^{-1}, which is comparable to Pt consumption in cars driven by internal combustion engine. However, with a continuous decrease in Pt loading, the oxygen transport resistance within the cathode catalyst layers (CCLs) is severely aggravated, therefore, it is very critical to explore strategies to greatly mitigate the transport resistance in CCLs of ultra-low Pt PEMFCs.

The oxygen transport resistance can be effectively reduced by exquisitely tailoring the CCL structure. It has been proved that the addition of pore-forming agent into the catalyst ink will lead to an increase in the porosity of CCLs, thus facilitating the oxygen transport. Nevertheless, so far, the mechanism of influences of pore-forming on the oxygen transport behavior has not been clarified, which is limited by unquantifiable transport resistances within CCLs. Here, this is well solved by employing a dual-layer CCLs design while magnesium oxide is added to its dummy catalyst layers (DCLs) as the pore-forming agent. Both the local and bulk resistances are thus measured directly and inspiring results are obtained. On one hand, it is surprisingly found that the bulk resistance rather is greatly reduced as the porosity increased, and the oxygen effective diffusivity ($D_{O_2}^{eff}$) almost doubles when the porosity increased from 53% to 65%. On the other hand, it is noteworthy that $D_{O_2}^{eff}$ obtained experimentally is two orders of magnitude smaller than that calculated based on the Bruggeman approximation, and the concept of effective porosity (ε^{eff}) is thus first introduced to amend the expression for effective diffusivity in CCLs of ultra-low Pt fuel cells. Finally, the as-obtained extremely low ε^{eff} (2.14% - 3.22%) also implies that there still exists huge spaces to improve the fuel-cell performance of ultra-low Pt PEMFCs via designing appropriate pore structures.

Keywords: ultra-low Pt loading, oxygen transport resistance, pore-formed electrode, oxygen effective diffusivity, effective porosity.

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COMPREHENSIVE DEGRADATION ANALYSIS OF PEMFC OPERATED UNDER CYCLING TESTS BY MORPHOLOGICAL AND CHEMICAL STRUCTURE ANALYSIS

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ABSTRACT

For analyzing the performance decrements caused by various factors (electrochemical, mechanical, chemical, etc.) of the PEMFC (Polymer Electrolyte Membrane Fuel Cell), the morphological analysis and chemical structure analysis of each layer of the MEA (Membrane Electrode Assembly) were performed after the load cycling test.

Nafion® PFSA was used for the ionomer in the electrolyte membrane and catalyst layer, and Pt-supported carbon was used for the anode and cathode electrodes. MEA after 28000 cycling tests and 56000 cycling tests were prepared under the potential cycle of 0.6 to 1.0 V.

After the durability test, the MEA was observed by non-destructive internal structure by high-resolution X-ray CT, and the cross-sectional observation and element distribution were analyzed by SEM-EDX and TEM. As a result, it was found that Si was contaminated in the cathode catalyst layer, and that Pt particles were enlarged in the cathode catalyst layer near the cathode gas outlet area. In addition, as a result of chemical degradation analysis (GPC, NMR, IC, LC/MS) of the electrolyte membrane and the ionomer in the catalyst layer, it was found that the deterioration was more likely to occur near the cathode gas inlet area.

Considering that together with the results of the CV curve and polarization characteristics, it was considered that the degradation of the cathode catalyst layer was the main cause of the performance decrements.

Keywords: PEMFC, Electrolyte membrane, Catalyst Layer, Electrochemical performance, X-ray CT, SEM, TEM, GPC, NMR, IC, LC/MS.

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LIQUID WATER TRANSPORT BEHAVIORS AT DIFFERENT AIR INLET FLOW RATES IN A PEMFC CATHODE WITH A BIOMIMETIC FLOW FIELD

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ABSTRACT

With zero-emission, fuel cells have demonstrated their potential as clean and effective energy conversion devices. Therefore, the interest in the deployment of technology of fuel cells, especially the PEMFCs (proton exchange membrane fuel cells), in transportation and residence sectors, has been rapidly growing. However, the performance, durability, and cost are still the main concerns for the widespread applications of PEMFCs. Those factors are greatly affected by the liquid water transport behaviors inside the PEMFCs: too much liquid water can cause flooding while the lack of water can cause dehydration of the membrane. For that reason, water management study is important for the development and application of PEMFCs. The biomimetic designs are capturing researchers' attention for the improvement of performance, reactant distribution, and low-pressure drop. Murray's Law, which is a mathematical description of common biological fluid distribution systems, is used for the biomimetic flow field design in this study since it shows better performance than the conventional designs. In order to numerically investigate the liquid water transport in this flow field design and the porous gas diffusion layer (GDL), a three-dimensional two-phase volume of fluid (VOF) model is implemented. In the simulation, the validated dynamic contact angle (DCA) model is also integrated to give a more accurate prediction of the liquid water distribution. With these models, the liquid water transport behaviors under several inlet air mass flow rates are investigated. The results of the numerical simulations reveal that the liquid water distribution and pressure drop inside the flow field are affected greatly by the air inlet flow rate.

Keywords: PEMFC, Volume of fluid method, dynamic contact angle, flow field design, biomimetic design.

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A NOVEL APPROACH IN IMAGING AND MAPPING OF IONOMER IN THE POLYMER ELECTROLYTE MEMBRANE FUEL CELL

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ABSTRACT

Materials characterization has been the main tool in understanding the structure-properties-performance relationship for a cathode catalyst layer in a proton exchange membrane fuel cell (PEMFC). The complex microstructure of PEMFC catalyst layers makes the materials characterization an effective approach to relate the loss of the PEMFC performance to its microstructural changes. Although there is a wide variety of available characterization techniques for PEMFC, the high resolution achieved with (scanning) transmission electron microscopy ((S)TEM) makes the observation of the nanosized features in the catalyst layer feasible. Also, the availability of powerful energy dispersive spectroscopy (EDS) in (S)TEM can provide the elemental distribution of the PEMFC components. Nevertheless, carrying out the imaging at the atomic resolution requires delicate sample preparation of a 100-200 nm thick section through many challenging available methods. The conventional and most convenient method of catalyst coated membrane (CCM) sectioning for TEM is embedding the CCM in epoxy resin and cutting thin sections with a diamond knife on an ultra-microtome. Although the technique has proven to be useful for the characterization of PEMFC nanoparticles and micropores, the procedure is not suitable for imaging the ionomer. The embedding resin surrounds the catalyst particles and agglomerates in the form of a thin layer with no contrast difference between carbon, embedding epoxy, and ionomer due to comparable densities. Also, “structural changes” of ionomer regions during the embedding [1] make the ionomer imaging in the epoxy-embedding technique highly challenging. Ionomer staining with heavy metals is another approach, however, the process often affects the original layer morphology due to ionomer swelling in the staining solutions [1]. While most of the successful ionomer imaging was reported in catalyst inks or model systems [2], very limited work has been reported for the catalyst layers of PEMFC [3,4]. For the first time, we report an epoxy-free technique of the whole commercial CCM, resulting in epoxy-free microscopy sections. The low magnification TEM results showed intact CCM with all three layers, i.e., anode, membrane, cathode, after sample preparation. The high magnification TEM and STEM images revealed an amorphous layer of a few nanometers thick ionomer covering the crystalline structure of Pt and carbon nanoparticles. Moreover, we report the analysis of a startup/shut down (SUSD) sample, prepared and sectioned by the same method, clearly showing the redistribution of ionomer and, what appears to be Pt ionic regions. The method was accompanied by high magnification EDS mapping of the ionomer, showing its distribution through the comparison of signal intensity of carbon and fluorine. The layer porosity reduction, reported by another novel quantification technique, based on epoxy-embedded EDS, was confirmed through the visual observation of carbon corrosion and changes of ionomer in the corrosion sites. Furthermore, the method can help to identify the corrosion initiation site. The promising results can open the window of opportunity for understanding the role of the ionomer in carbon corrosion, Pt dissolution/redeposition, and catalyst layer structure changes.

Keywords: PEM fuel cell, characterization, ionomer, microtomy, epoxy-free.

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SYNTHESIS AND TRANSMISSION ELECTRON MICROSCOPY (TEM) CHARACTERIZATION OF PLATINUM ON CARBON NANOPARTICLES SELECTIVELY COATED WITH TITANIUM NITRIDE (TIN)

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ABSTRACT

The growing concerns regarding energy supply and environmental issues have placed considerable emphasis on the development of clean alternatives to conventional energy sources. From the currently available green technologies, Proton Exchange Membrane Fuel Cell (PEMFC) is one of the most advantageous solutions for energy applications due to its near-zero-emission, high efficiency, low maintenance cost, and high energy density. Platinum nanoparticles (Pt NPs) are the preferred catalyst in these systems, due to their high activity and stability, even though their scarcity makes it expensive for widespread fuel cell application and commercialization. For this reason, carbon C is generally used as catalyst substrates to disperse Pt NPs because of its good electrical conductivity and high surface area. However, the operating conditions and the intrinsic environment in which PEMFC works make the carbon supports prone to corrosion and subsequent degradation, which eventually leads to performance losses in a PEMFC. Additionally, the corrosion of the carbon support can induce the loss of Pt NPs active surface area due to its detaching from the support, Pt NPs growth and Pt NPs agglomeration. In this research, we propose a novel way to prevent the carbon corrosion by coating the Pt/C catalyst (in powder state) with a corrosion resistant layer of titanium nitride (TiN). The goal is to selectively coat the carbon support, while leaving the Pt catalyst centers uncoated and accessible for reagents reactions (oxygen O and H+ protons). This TiN coating is electronically conductive enough to allow electron transport from the current collector toward the catalytic centers. The TiN layer (approximately 1.5 nm thick) was deposited by hollow-cathode plasma-assisted atomic layer deposition (HCPA-ALD) using tetrakis(dimethylamino)titanium (IV) (TDMAT) and Ar/N2 plasma as the metal precursor and nitrogen co-reactant at 150°C. During ALD, it was important to always maintain the Pt NPs protected from TiN deposition on their surfaces by screening them with a thin film of oleylamine, a polymer that would only absorb onto Pt NPs, which is later removed from the catalyst and TiN system (after the ALD process is over), by heat treatment. Here we will mainly focus on the Transmission Electron Microscopy (TEM) characterization done on these nanoparticles, which allows us to prove the successful formation of homogenous coatings and architecture characteristics of these nanoparticles after oleylamine application and TiN ALD. Our preliminary results have shown that highly conformal TiN can be successfully grown onto Pt/C powder nanoparticles by using HCPA-ALD with a custom-made agitator mechanism. The second phase of this research will be focused on the electrochemical responses of the TiN coated catalysts and the effect TiN coating has on its catalytic response, as well as inspecting the degradation mechanisms this novel catalyst system experiences after potential cycling.

Keywords: PEMFC, Pt NPs, TiN, ALD, carbon corrosion.

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EFFECT OF CATALYST INK FOMULATION AND DISPERSION PROCESS ON CATALYST LAYER MICROSTRUCTURE AND FURTHER ON PERFORMANCE AND DURABILITY OF PEMFCS

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ABSTRACT

Catalyst layer (CL), a key component of proton exchange membrane fuel cells (PEMFCs), is composed of intersecting and continuous networks of supported Pt-based catalyst, ionomer, and pore. The microstructure of CLs plays a significant role in the formation of three phase boundary and transport properties of electron, proton, reactant, and product, which determines the PEMFCs' performance, durability, and cost. However, it is still a challenging to rationally design and successfully fabricate the CLs with desired microstructure for PEMFCs. The CLs are primarily manufactured by catalyst ink processing method. The catalyst ink is prepared by homogeneously dispersing supported Pt-based catalyst and ionomer with a certain weight ratio in solvent, whose macroscopic properties and microstructure govern the microstructure of CLs and further the performance and durability of PEMFCs to some extent. However, the relationship between them is still unclear and even inconsistent in some cases. This presentation reviews the advanced development of the effect of the properties of catalyst, ionomer, and solvent, as well as the dispersion process on catalyst ink's macroscopic properties and microstructure, including rheological behavior, surface tension, stability, coatability, and aggregates and interface of catalyst and ionomer. The relation among the catalyst ink's macroscopic properties and microstructure, microstructure of CLs, and performance and durability of PEMFC is analyzed based on the literature studies. Finally, the challenges and future directions of the studies on their relationship are described.

Keywords: Catalyst ink, Catalyst layer, PEMFC, Macroscopic properties, Microstructure.

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ANODE RECIRCULATION STRATEGY OPTIMIZATION FOR PROTON EXCHANGE MEMBRANE FUEL CELL BY SEGMENTED CELL TECHNOLOGY

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ABSTRACT

Improving the utilization efficiency of hydrogen is very important for the commercialization of proton exchange membrane fuel cells, and the optimization of anode recirculation strategies is one of the effective methods. In this study, the effect of different anode recirculation strategies on the fuel cell performance and fuel utilization rate is investigated experimentally using a variety of parameter tests, such as high-frequency resistance (HFR), electrochemical impedance spectroscopy, H_2 inlet flow rate and pressure drop. The voltage stability of different recirculation strategies and flow-through tests in ideal conditions (RH100%/RH100%) and simulated actual conditions (RH50%/Dry) are compared, and the anode recirculation strategies are optimized by segmented cell technology. In different anode recirculation strategies, as the power of anode recirculation pump decreases, the fuel cell performance improves, and the overall system efficiency increases. 20% recirculation test has the highest performance. This strategy is more suitable to be applied in actual conditions with low humidity. The results indicate that the fuel cell performance of 20% recirculation only lost 6.25%, and the fuel utilization rate increased from 47.36% to nearly 100%, compared with the flow-through test.

Keywords: PEMFC, anode recirculation, current density distribution, fuel utilization rate.

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LIQUID WATER TRANSPORT BEHAVIOR OF ELECTROSPUN GAS DIFFUSION LAYERS WITH FINE-TUNED PORE SIZE GRADIENTS

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ABSTRACT

Water management is one of the obstacles affecting the large-scale commercialization of proton exchange membrane fuel cell (PEMFC) technology. Located between the gas flow channel and the catalyst layer (CL), gas diffusion layers (GDLs) play an important role in water management. To avoid both GDL flooding and membrane dehydration under high current density and low humidity operation conditions, the pore structure of GDLs needs to be precisely tuned. In this work, electrospun gas diffusion layers (e-GDLs) with fine-tuned pore size gradients were fabricated by electrospinning and hydrophobically treated by physical vapor deposition of Dow Corning Sylgard 184. Through breakthrough pressure and water retention tests, it is found that the largest breakthrough pressure of the hydrophobically treated e-GDL sample (termed 3-MG) is about 8.5 folds higher than that of commercial GDL (SGL29BC), while the water retention of the 3-MG sample is only 34% of the SGL29BC sample. This superior characteristic is expected to simultaneously alleviate GDL flooding and membrane dehydration under high current density and low humidity operation conditions.

Keywords: PEMFCs, Electrospun gas diffusion layers, Pore size gradients, Breakthrough pressure, Water retention.

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EFFECTS OF THERMAL CONDUCTIVITY OF ELECTRODES ON THE PERFORMANCE OF PROTON EXCHANGE MEMBRANE FUEL CELLS

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ABSTRACT

In this study, the electrochemical and heat and mass transfer characteristics of PEMFC with anisotropic electrode thermal conductivity at different ambient temperatures in the current channel model were systematically analyzed. The results show that the anisotropic electrode thermal conductivity condition is reducing the thermal conductivity in Z-direction and is more obvious than other directions. From the temperature distribution, the reaction heat generated by electrochemical process is the main heat source in PEMFC, and the temperature of cathode is also significantly higher than that of other regions. In addition, the molar concentration distributions of liquid water and oxygen on the electrode surface are also vary at different ambient temperatures, which is due to the competition between the two mechanisms of water produced by electrochemical reaction and the phase transition from liquid water to gas at high temperature. In conclusion, the output performance of PEMFC can be effectively improved by appropriate anisotropic thermal conductivity along Z-direction at low ambient temperature, but the improvement of electrochemical reaction performance is limited by high ambient temperature. The performance of PEMFC can be effectively improved by designing electrode materials with reasonable anisotropic thermal conductivity along Z-direction based on different ambient temperatures.

Keywords: PEMFC, electrode, anisotropic, thermal conductivity.

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LONG-RANGE ORDERED PT-BASED NANOCATALYSTS FOR OXYGEN REDUCTION REAACTION - ABSTRACT PREPARATION FOR WFCC 2020

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ABSTRACT

Proton exchange membrane fuel cells (PEMFCs) have attracted much attention as a clean and mobile power source due to the high energy density by using hydrogen as the fuel. For years, the default metallic material for the anodic and cathodic electrodes has been platinum (Pt) due to its enhanced activity and stability. The commercial PEMFCs usually use carbon-supported Pt nanoparticles (NP) catalysts (Pt/C) for the oxygen reduction reaction (ORR) in cathode and the hydrogen oxidation reaction (HOR) in anode. Pt NPs disperse messily on the carbon supports, which is not beneficial for the electrode reaction and product transmission. As the Pt-based NPs orderly distributed on the supports, combined with the unique small size effect and surface effect of the nanomaterials, the high activity and stability of the Pt NP catalysts can be achieved.

Self-assembly is an effective and important method in the material synthesis aiming to prepared hierarchical micro- and nano-scale structures [1]. The so-called “bottom-up” nano-template formed by the molecule self-assembly, with well-arranged Pt NPs, can obtain PEMFC catalysts with high catalytic activity and stability. This study presents the ordered nanostructures, such as pseudo-hexagonal network, hexagonal dots and mesoporous honeycombs, assisted by self-assembly [2,3], effectively improving the utilization and the activity of Pt. The ordered structure is maintained in electrode processing and NP transfer, which is desirable for realizing the ordered arrangement of the channels of protons, electrons, gas, and water and greatly enhances the ORR activity and stability in the single cell tests.

Key words: Ordered nanostructure; Pt-based nanoparticles; ORR; PEMFC

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Highly Dispersed PtCo Nanoparticles on Self-Assembled Hierarchically Ordered Mesoporous Carbon Support for Polymer Electrolyte Membrane Fuel Cells

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ABSTRACT

PtCo nanoparticles (NPs) on hierarchically ordered mesoporous carbon (PtCo/OMC) are synthesized for polymer electrolyte membrane fuel cells (PEMFCs) aiming to improve the catalytic performance of the Pt-based catalyst towards oxygen reduction reaction (ORR). Specifically, a triblock copolymer PEO-PPO-PEO is employed as the structure agent to prepare the OMC through a solvent evaporation induced self-assembly (EISA) method, followed by annealing in the nitrogen atmosphere. The block copolymer-derived carbon shows a large surface area (495.65 $m^2 \cdot g^{-1}$), uniform mesoporous structure and a high degree of graphitization. PtCo nanoparticles (NPs) are fabricated with an average diameter of 3.3 nm by H_2 reduction and galvanic replacement in an acid solution, and then are uniform dispersed onto the OMC via wet impregnation. The unique mesoporous structure of the OMC enhances the uniformly distribution and thermal stability of the PtCo NPs. The PtCo/OMC catalyst exhibits excellent activity and stability in the cyclic voltammetry (CV) and single cell test. In the electrochemical tests, PtCo/OMC shows a large electrochemically active surface area (ECSA) of 88.56 $m^2 \cdot g^{-1}$, and a ECSA retention of 77.5 % after 5000 CV cycles. The PtCo/OMC has excellent physical properties and shows enhanced catalytic performance, which endows it with great potential in future PEMFC applications.

Keywords: PtCo nanoparticles, block copolymer self-assembly, ordered mesoporous carbon, oxygen reduction reaction, polymer electrolyte membrane fuel cells.

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ON THE UNEXPECTED VOLTAGE LOSS IN POLYMER ELECTROLYTE FUEL CELLS AT ULTRA LOW-PLATINUM LOADING - A WATER BALANCE MODEL

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In order to substitute fossil-supplied internal combustion engines, hydrogen-fed fuel cells need to achieve high power while reducing cost by using minimal amount of noble metal catalyst. Experimental studies have shown, aside from kinetic losses, substantial voltage losses upon lowering the Pt loading in the cathode catalyst layer, which is termed “the unexpected voltage loss”. To explain this trend, we present a water balance model in the cathode catalyst layer and diffusion medium accounting for the fine interplay between water production, vaporization and transport, and an interfacial liquid transport model at the interface between diffusion medium and flow field. Water fluxes and saturations in these components are solved. Our work shows that reducing the Pt loading induces a shift of the balance between rates of water production and vaporization, which leads to a build-up of the liquid water pressure and thereby the saturation in the cathode catalyst layer and diffusion medium. The resulting sluggish oxygen transport is concluded to be the origin of the additional voltage loss.

Keywords: PEM fuel cell, low Pt-loading, unexpected voltage loss, water balance.

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PERFORMANCE AND DURABILITY STUDY OF PEM FUEL CELLS MADE OF CATALYSTS WITH NON-SPHERICAL PLATINUM NANOPARTICLES OF DIFFERENT SIZES

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ABSTRACT

Hydrogen fuel cell has high efficiency and zero emissions, ideal as alternative power sources for decarbonization effort. In the development of the proton exchange membrane fuel cell (PEMFC) technology, developing higher-performing and more durable catalysts with low cost is essential for its success in commercialization. In this study, two different sizes of Platinum (Pt) Nanoparticles, 2nm and 5nm, with non-spherical shapes and supported on functionalized high surface area carbon (HSC) have been synthesized with a one-pot synthesis technique. The synthesized supported catalysts are evaluated by physical characterizations, half-cell electrochemical characterizations, and scaled up single-cell tests to study the impact of the Pt nanoparticle size on cell performance and durability. The results indicate that both catalysts show excellent performance and durability, while the catalyst with the smaller Pt nanoparticle size (2nm) shows higher electrochemical surface area, higher mass activity and higher maximum power density, and the catalyst with the larger Pt nanoparticle size (5nm) shows greater durability against degradation in the accelerated stress test.

Keywords: Pt/C catalyst; Pt particle sizes; Mass activity; Durability; Proton exchange membrane fuel cells (PEMFC)

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MECHANISTIC MODELING AND OPTIMIZATION OF ALTERNATE HYDROGEN PUMP METHOD OF COLD START OF PEFC

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ABSTRACT

Cold start remains an obstacle for the commercialization of fuel cell vehicles in cold areas, especially for those with graphite bipolar plates (GBP) due to the high thermal capacity. The self-heating method using a high concentration overpotential developed by Toyota stands the ordeals of start-up from −30°C on metallic bipolar plates fuel cell stacks. However, with an upper limit of heat generation, that self-heating method has not been proved to be capable in the situation requiring a high yield of heat, in specific, a −30°C start-up on GBP fuel cells. Under such circumstances, the cold start with the self-heating method will suffer from failures and freezing of supercooled water according to our estimation model. On the contrary, auxiliary heating methods with guaranteed capability and robustness match the demand of the cold start of the GBP fuel cell stacks. However, the commonly used coolant heating method has low energy efficiency and heating rate, and the electric heating method requires embedding the heating wires into the stack. In order to achieve a capable and efficient cold start, our previous study proposes the alternate hydrogen pump (AHP) method and achieved −30°C start-up on the GBP single cell under the isothermal boundary condition. The mechanism and the optimization of the AHP method remain to be explored.

This study develops a model after diving into the resistance behavior of the AHP method. The model is verified by the −30°C start-up experiments under the adiabatic boundary condition. Membrane water distribution and water vapor outflow are found to be the determinant mechanisms of the resistance behavior. Based on the mechanistic model, the strategy contains the high alternate voltage frequency and the circulation hydrogen flow control is proposed to optimized the AHP method under constant voltage. The optimized method is compared with the Toyota's self-heating method in terms of capability, robustness, start-up rate, energy efficiency, and the possibility of corrosion. The AHP method with high capability, high energy efficiency, and high heating rate is promising for the cold start of GBP fuel cells.

Keywords: PEFC, cold start, alternate hydrogen pump method, resistance behavior, optimization

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THREE-DIMENSIONAL MODELING AND ANALYSIS OF PEMFCS WITH LOW PT LOADING REGARDING INITIAL PERFORMANCE AND PERFORMANCE AFTER PT DEGRADATION

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ABSTRACT

Cost and durability are the two major challenges limiting the full market penetration of PEMFCs in automotive industries. Cathode catalyst layer is important from both aspects of cost and durability. Reducing the cathode catalyst Pt loading is effective in suppressing the PEMFC cost as Pt is a noble metal, but it poses issues in PEMFC performance due to the local oxygen resistance effect. As for the lifetime performance, the low Pt loading PEMFCs are prone to suffer voltage loss as the Pt degradation further amplifies the local oxygen resistance, resulting in very large oxygen concentration polarization and significant reduction of the PEMFCs limiting current density. Regarding the automotive PEMFCs, the dynamic load condition inevitably induces Pt degradation in cathode catalyst layer. Thus, the low Pt loading PEMFCs not only suffers problems in their initial performance, but also faces critical issues of performance decay caused by Pt degradation. Furthermore, establishing of modeling method to study the initial performance and performance after cathode catalyst Pt degradation is essential. Quantitative analyzing of the impacts for reducing cathode catalyst loading could provide fundamental insights for understanding low Pt loading catalyst layer. Three-dimensional modeling of the low Pt loading PEMFCs is performed in this study by employing a local oxygen transport model and its integration into a multi-physics PEMFC modeling scheme to count the low Pt loading effect. The effects of important parameters, such as operating pressure, cathode stoichiometry, and cathode channel/land width on the low Pt loading PEMFC performance are specifically discussed. The oxygen concentration, current density distribution fields are analyzed. It is found, the PEMFCs with low cathode Pt loading is much more sensitive to the operating pressure, cathode stoichiometry, and cathode channel/land width than the PEMFCs with regular Pt loading. Those findings are meaningful in guiding the design of realistic automotive PEMFCs with low cathode Pt PEMFCs. Then, the performance of PEMFCs with low and regular cathode Pt loading under the electrochemical surface area (ECSA) loss, which is major consequence of cathode catalyst degradation, are compared by numerical simulations. Underlying mechanisms of the low Pt loading PEMFCs performance loss after Pt degradation are revealed. The three-dimensional modeling conducted in this work provide a method for in depth understanding the PEMFCs with low cathode Pt loading. In addition, it provides an effective designing tool for industrial automotive PEMFCs, paving the way for achieving PEMFCs with better performance and durability.

Keywords: PEMFCs, Low Pt Loading, Modeling, Performance, Degradation.

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PROTON CONDCUTION MECHANISM OF IONOMER NANOFIBER: NON-MONOTONIC SIZE EFFECT

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ABSTRACT

The success of PEFC lies on the birth of PFSA ionomer, consisting a tetrafluoroethylene polymer backbone and flexible side chains terminated with a sulfonic acid ($SO3^-H^+$) group. Protons pass through the charged sulfonic acid sites in hydration state and participate in oxygen reduction reaction (ORR). The proton conductivity of ionomer network in membrane and catalyst layer greatly limits the performance of fuel cell. To facilitate proton conduction, researchers developed ionomer nanofibers with superior conductivity by electrospinning method. Elabd et al. reported a nanosized effect, where proton conductivity increases sharply with decreasing fiber diameter. They attributed this effect to oriented ionic morphology along the nanofiber axis direction. Their results implied the thinner the nanofiber, the better the performance. However, in their measurement, the contact between nanofiber and electrode is not controlled. This uncertainty may mislead the results. In this work, we explored the effect of contact on impedance measurement and presented a method to ensure good contact between nanofiber and electrode. Based on this, we measured the conductivity of ionomer nanofiber with diameter from 50 nm to 5 μm at different temperature and relative humidity. We found a non-monotonic size effect, where proton conductivity firstly increases with decreasing fiber diameter due to oriented ionic morphology, and then decreases when the diameter becomes comparable to the size of the aqueous regions of the ionomer. This work can provide guidance to the design of components composed of ionomer nanofiber.

Keywords: PEFC, ionomer nanofiber, proton conductivity, size effect.

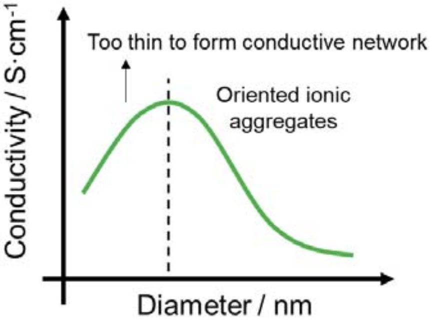

Figure 1 The schematic of non-monotonic size effect on proton conductivity of ionomer nanofiber.

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NANOFIBER UNIT MODEL FOR ELECTROSPUN CATALYST LAYER

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ABSTRACT

Electrospun nanofiber catalyst layers have presented outstanding properties in performance, durability, and water management, compared with agglomerate-structure catalyst layers. However, until now, the underlying causes of the performance improvement are not well understood. The current research of electrospun catalyst layers is still at the stage of trial and error, and optimization methods for electrospun catalyst layers are very scarce. Here, a nanofiber unit model for deciphering the structure and performance relationship in the electrospun catalyst layer was developed. The nanofiber structures were input from experimental results. The nanofiber morphology including diameter distribution and nanofiber length distribution were characterized with SEM. The Pt distribution and ionomer distribution were also investigated and the non-uniform Pt and ionomer distribution were found. More Pt accumulates at the center of the nanofiber, and more ionomer distributes at the exterior surface of the nanofiber. The performance of catalyst layers was evaluated under a wide range of relative humilities.

In this model, the electroneutrality law at the single nanofiber was used to describe the local proton conductivity. The ohmic law was introduced to describe the electrolyte potential distribution. The oxygen transport was described with Fick's law. An interface sub-model was developed to determine the surficial reaction conditions based on the refined structural model of Pt-water interface from Jun Huang et al [1]. The oxygen reduction reaction rate is determined by the refined B-V equation. The effects of nanofiber diameter, Pt and ionomer distribution at the cross-section of nanofiber were investigated, calibrated with experimental data. Optimized Pt and Ionomer distribution were predicted by the model. The nanofibers with less diameter could be beneficial to mass transfer. A uniform ionomer distribution at the cross-section and more Pt at the center will further improve the performance.

Keywords: Fuel cell, electrospun catalyst layer, Pt distribution, diameter.

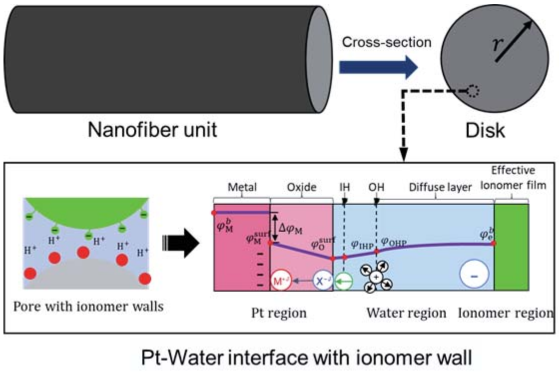

Fig 1 The diagram description of the nanofiber unit model

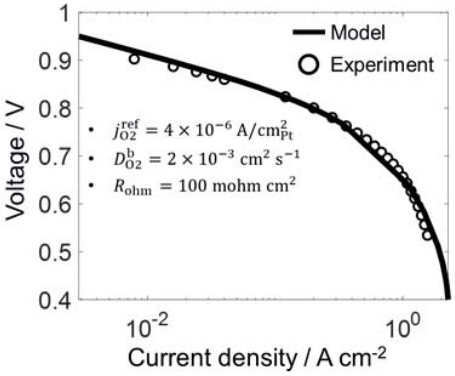

Fig 2 Polarization curves between modeling results and experimental results

Reference

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Effect of Gas Transport Resistance of Ionomer Covering on Platinum Surface on Catalyst Layer Performance

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ABSTRACT

Resistance of oxygen transport through ionomer to platinum surface R_{ion} limits the performance of polymer electrolyte fuel cell (PEFC) catalyst layer (CL), especially for that with low platinum loading. However, the accurate description of the effect of R_{ion} on CL performance rarely exists. Such a research missing stems from the difficulty on accurate measurement of R_{ion}. In existing works, R_{ion} is extracted from the limiting current density in dilute oxygen or hydrogen atmosphere. Because of the difficulty on CL diffusion coefficient D_{CL} measurement, the gas distribution through CL thickness is usually ignored[1]. However, our model indicates that such a simplification is improper for CL with small diffusion coefficient and leads to large measurement error as Fig.1 shows. Due to the limitation R_{ion} accuracy, the evaluation of the effect of R_{ion} on CL performance lacks credibility even with well-established model. Besides that, such a model coupling R_{ion} and CL performance is still lacking. To address the effect of R_{ion} on CL performance, we established a CL model in consider of R_{ion} and ionomer coverage θ_{ion}, and the input parameter comes from accurate experimental measurement. To measure R_{ion} accurately, a physics-based electrochemical impedance spectroscopy (EIS) model considering gas transport in CL pores and gas transport through ionomer to Platinum surface is established, and R_{ion} is extracted from the EIS testing result. In order to increase the signal/noise ratio, gas diffusion layer (GDL) is replaced with gold mesh. To measure θ_{ion}, CO adsorption experiment under different gas atmosphere and humidity is conducted. The research result reveals that R_{ion} is influential on CL performance under low Platinum loading and small gas excess ratio conditions.

Keywords: PEFC, catalyst layer, gas transport resistance of ionomer, EIS

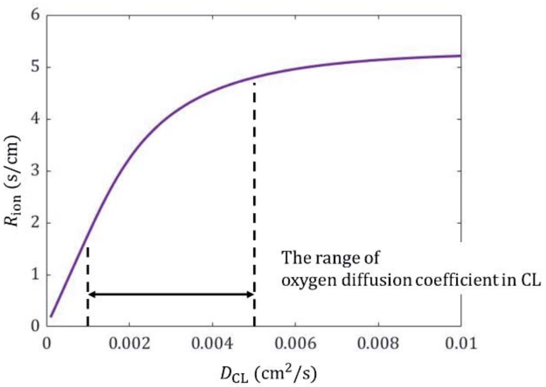

Fig. 1 The influence of D_{CL} on R_{ion} measurement result

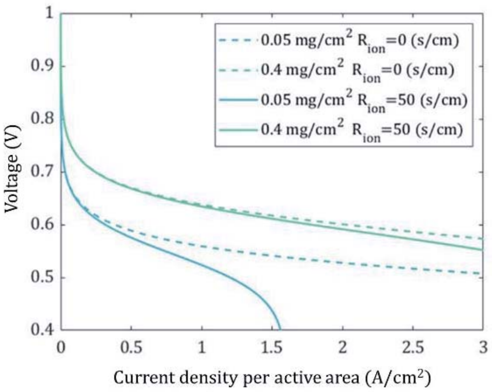

Figure 2 The influence of R_{ion} on PEMFC performance

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INTERFACE CHARACTERISTICS AND IONOMER COVERAGE OF ELECTROSPUN CATALYST LAYERS FOR POLYMER ELECTROLYTE FUEL CELLS

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ABSTRACT

Catalyst layers (CLs) are the key components to decide the performance and durability of fuel cells. Three types of catalyst layer structure have been developed to increase catalyst utilization and effectiveness, including agglomerate structure, column arrayed structure, and fiber alignment structure. The fiber alignment structure catalyst layers are mainly prepared by electrospinning technology, and the electrospun catalyst layers have been proved to have higher performance and durability than agglomerate-structure catalyst layers. However, the fundamental understandings of the performance improvement are very scare. Here, electrochemical diagnostics, including the electrochemical surface area (ECSA) and the electric double-layer capacitance, were utilized to investigate the interface characteristics and estimate the ionomer and water coverage. Then the pore structure characterization were conducted to measure the pore size distribution and surface area. Based on the quantitative analysis of surface area, ionomer coverage and pore structure, it can be concluded that the nanofiber structure of electrospun CLs could expose more micropore and mesopore space inside the catalyst layer, and increase the surface area of Pt and carbon, especially for the surface area related to water. Less ionomer coverage ratios for electrospun CLs were found, and it supports the published results that more ionomer is distributed on the exterior of the nanofiber and more catalysts aggregate at the interior of the nanofiber.

Keywords: Fuel cell, double-layer capacitance, ionomer coverage, electrospun catalyst layer.

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[i] These authors contributed equally to this work.

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HYBRID HYDROPHILIC–HYDROPHOBIC ELECTROSPUN MICRO-POROUS LAYER FOR PROTON ELECTROLYTE FUEL CELLS

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ABSTRACT

The micro-porous layer (MPL), between catalyst layers (CL) and gas diffusion layers (GDL), is significant to improve the fuel cell performance. Previous studies proved that the electrospun MPL can effectively improve the water management ability under high relative humidity (RH) conditions by reducing the mass transfer voltage losses. However, the performance under the low RH of electrospun MPL remains to be improved based on published results. The hydrophilicity and hydrophobicity of MPL are the key to improving the fuel cell performance under the low RH. Enhanced hydrophilicity for MPL should be strengthened under low RH to increase the water retention capability. Here, the electrospinning technique was used to fabricate a hybrid hydrophilic–hydrophobic MPL (H-hybrid MPL) with a double-layer structure, as shown in Figure 1(a). The hydrophobic layer was fabricated with the ink consisting of polyvinyl pyrrolidone (PVP), acetylene black and ethanol, and the hydrophilic layer was made with the ink consisting of polyacrylonitrile (PAN) and N,N-Dimethylformamide (DMF). After electrospinning the double-layer structure, a hot processing was conducted to carbonize the polymer to form stable and porous MPL with high electric conductivity. Polarization curves from the low RH to high RH of the fuel cells were evaluated with the H-hybrid MPL, compared with commercial MPL (SGL 29BC). High performance with H-hybrid MPL was obtained at low and high RHs, compared with the commercial MPL. Under 100% RH, the H-hybrid MPL outperforms the commercial MPL, especially under the large current densities. The voltage losses method indicates that the H-hybrid MPL shows a lower mass transfer voltage loss, as shown in Figure 1(b). Furthermore, under 40% RH, the H-hybrid MPL still shows a lower mass transfer voltage loss, as shown in Figure 1(c). Our experimental results indicate that the H-hybrid MPL could improve the fuel cell water management under both low RH and high RH by decreasing the mass transport resistance.

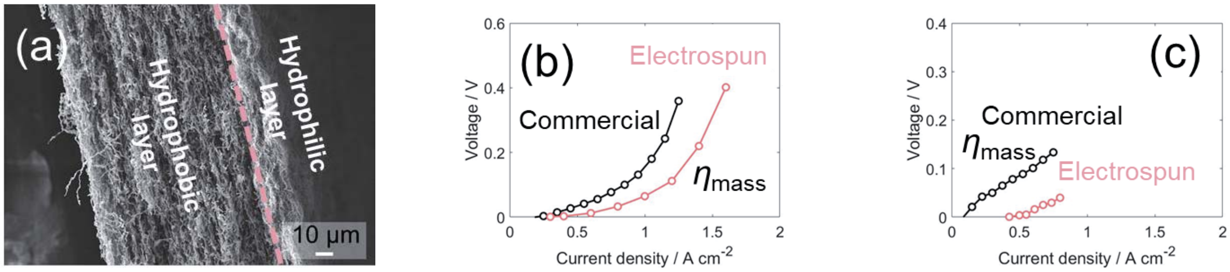

Figure 1: (a) Cross-sectional image of H-hybrid MPL; Comparison of mass transfer voltage loss: (b) 100% RH and (c) 40% RH (test conditions: 80℃, anode 200 sccm, cathode 300 sccm).

Keywords: Fuel cell, microporous layer, water management, electrospinning

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INTERPRETATION OF THE LOW-FREQUENCY INDUCTIVE BEHAVIOR IN IMPEDANCE SPECTRA OF PEFCS

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ABSTRACT

Electrochemical impedance spectroscopy (EIS) is an in-situ, noninvasive method that has been widely used to investigate PEFCs.[1] EIS can separate interfacial reactions and mass transport processes in a wide frequency range.

In many cases, an inductive loop exists in the low-frequency region of the impedance spectrum. Current understanding of the low frequency inductive behavior is still in debate. Researchers attribute this phenomenon mainly to three physical process. The first school of thought attributes it to the multi-step oxygen reduction reactions with adsorbed intermediates on Pt surface.[2] The adsorption and desorption of intermediates result in the inductive loop. The second school attributes it to platinum oxide growth.[3] The adsorption of platinum oxidation generates the inductive loop.. The third school attributes it to water transport in membrane and anode catalyst layer.[4] The humidity dependent properties of the membrane and catalyst layer lead to inductive behavior.

In this work, we develop a unified model considering all of the three mechanisms in order to find the dominant one. We find that the low frequency inductive loop behaves differently when different mechanism dominates, providing clues to distinguish them experimentally. The inductive behavior is more obvious in low relative humidity conditions, when the water transport mechanism dominates. In high relative humidity conditions, the importance of water transport diminishes. Multiple step oxygen reduction reactions mechanism dominates in middle voltage and high relative humidity conditions. The mechanism of platinum oxidation dominates in relative high voltage and high relative humidity conditions. We get the impedance spectrum experimentally at different relative humidity and cell voltage. By fitting with electrical equivalent circuit models, we identify the characteristic parameters representing the low frequency inductive behavior. We draw one MAP figure showing characteristic parameters of the total inductive behavior with varying voltage and relative humidity. Besides, the MAP figure also reveals the contributions of different mechanisms to the total inductive behavior at different operating conditions, deepening the understanding of the existence of low frequency inductive behavior.

Keywords: EIS, PEFC, Low frequency inductive behavior.

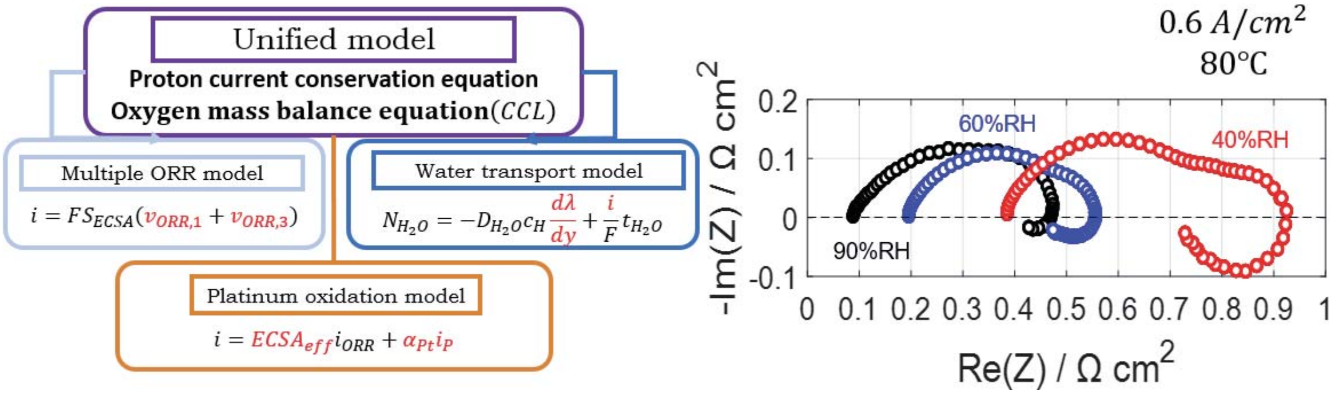

Figure 1 The construction of the unified model and partly experimental impedance spectrum at different relative humidity

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MULTI-SCALE STUDY ON BIFUNCTIONAL M–N–C CATHODE CATALYST LAYERS FOR HYDROGEN FUEL CELL

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ABSTRACT

With the ultimate goal of developing cheap and high-performance catalyst layers (CLs) based on non-precious group metal (non-PGM) catalysts, much work has been devoted to designing catalysts with high porosity and efficient active sites. Although very promising results are achieved using Co/Fe–N–C catalysts based on rotating disk electrode (RDE) tests during laboratory investigation, actual fuel cell performance is below expectations, probably due to insufficient understanding of the CL. Therefore, catalyst design should be considered holistically by taking into account CL performance, not only the intrinsic activity of catalyst. Here, Co/Fe–N–C with highly dispersed CoFe nanoalloy in the carbon network is obtained by careful design of Co/Fe-ZIF precursor, resulting in a high oxygen reduction reaction (ORR) site density with good stability in both 0.1 M KOH and 0.1 M $HClO_4$. Concerning RDE test in the kinetic region and single-cell test (SCT) with complex influence factors, the half-cell test (HCT) is introduced to more accurately evaluate the quality of the Co/Fe–CL, which exhibits a high current density > 100 mA cm^{-2} (0.77 V_{RHE} in KOH, 0.59 V_{RHE} in $HClO_4$). Multi-scale research in different current density ranges (RDE, HCT, and SCT) allows targeting the key CL influence factors for fuel cell performance. This work integrally introduced the good performance of CoFe nanoalloy catalyst for ORR, from material design and simulation analysis to fuel cell application, which not only provides a synthetic method for high-performance ORR catalyst, but also highlights the multi-scale strategy for the fast and accurate evaluation of fuel cell catalyst and catalyst layer.

Keywords: alloy nanocluster; oxygen reduction reaction; electrocatalyst; half-cell test; polymer electrolyte membrane fuel cells

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TOLERANCE OF MEMBRANE WITH ADDITIVE TO IRON CONTAMINATION IN PEM FUEL CELL

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ABSTRACT

Contamination is one major contributor to the degradation of proton exchange membrane (PEM) fuel cell performance and lifetime. Aiming to evaluate the tolerance of PEM with the state-of-the-art membrane additives to metal ions contamination, iron (Fe) ion was selected in this work as a representative of impurities that could come from most of the composition of current metal bipolar plates and directly introduced into the membrane. It has been found that the membrane additives not only could provide durability benefits but also could enhance Fe^{3+} contamination tolerance without any performance loss. These scientific findings provide valuable guidelines for membrane developers and PEM fuel cell manufacturers in quality control (QC) during the production of fuel cell components.

Keywords: Proton exchange membrane (PEM); Fuel cell; Additives; Iron contamination; Degradation.

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PEMION®: FULLY HYDROCARBON PEMFCS FOR HIGH TEMPERATURE EXHIBITING PERFORMANCE AND DURABILITY

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ABSTRACT

An exciting evolution in the realm of hydrocarbon-based polymer electrolyte membranes (PEMs) has occurred within the last five years. This new era in PEM development represents an emphasis on materials that simultaneously exhibit improved performance across a wider range of operating conditions, and greater combined chemical-mechanical stability, when integrated into a state-of-the-art fuel cell. These modern hydrocarbon PEMs outperform previous generation hydrocarbons and, for the first time, incumbent perfluorinated sulfonic acid-based materials as well. Hydrocarbons address critical issues with perfluorinated sulfonic acid (PFSA) materials. Reduced gas crossover allows longer component lifetimes, operational window for system pressures, and reduced hydrogen venting. Higher temperature tolerances allow system operation or excursions to ≥ 100 °C, which affords a myriad of potential benefits such as reduction in heat exchanger volume, increased membrane conductivity due to reduced Ohmic losses, improved system water management, and increased catalyst activity due to reduced activation losses. Furthermore, higher operating temperatures go hand-in-hand with greater pollution tolerance, and hence reduced hydrogen purity requirements.

The award-winning hydrocarbon PEM, PemionTM, produced by Ionomr Innovations, is nested at the center of these exciting developments. Hydrogen fuel cells wholly comprised of hydrocarbon ion-exchange components – PemionTM ionomer in the catalyst layer atop reinforced PemionTM membranes – are imaged, evaluated, and compared to cells comprised of short side chain (SSC) perfluorosulfonic acid (PFSA) materials. The catalyst-coated hydrocarbon membranes show excellent consistency, adhesion, and uniformity, as is typically observed for PFSA-based materials. Under industrially-relevant operational conditions, fuel cells comprised of PemionTM exhibit performance nearly indistinguishable to that of the PFSA counterparts. Although the performance of PemionTM cells is more dependant on relative humidity, the influence of high temperatures on performance is significantly lessened. Increasing operating temperature from 80 to 100 °C exerts a negligible impact on performance and small increase in area resistance in cells comprised of PemionTM compared to optimized SSC PFSA fuel cells, with a differential of up to 10%. The net consequence of these findings are fully hydrocarbon hydrogen fuel cells that, under standard H_2/Air conditions, exhibit unprecedented peak power densities exceeding 1.1 W/cm^2.

Keywords: N/A

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IMPROVING ION CONDUCTIVITY IN ANION EXCHANGE MEMBRANES BY UTILIZING POLYMERS OF INTRINSIC MICROPOROSITY (PIMS)

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ABSTRACT

Fuel cells are promising energy conversion devices, which require high ion conductivity and stability for polymer electrolyte membranes (PEMs). Porous organic frameworks (POFs) offer an opportunity to function as potential PEMs owing to their highly permeable porous structure and modifiable organic nature. Unfortunately, most POFs tend to be insoluble, rendering it difficult to fabricate defect-free membranes. Polymers of intrinsic microporosity (PIMs), such as PIM-1, are soluble in organic solvents and are readily cast into membranes.

Here, we report PIM-1 based defect-free POFs as anion exchange membranes (AEMs), obtained by a facile two-step post-modification. A series of pendant quaternized ammonium-modified PIM-1 membranes (QPIMs) were fabricated with various ion exchange capacities (IECs). The structure-performance relationship was investigated by comparison with a traditional dense AEM, quaternized polyphenylene oxide (QPPO). QPIMs inherit intrinsic interchain microporous structure of pristine PIM-1 membrane, while the H_2 permeability of hydrated QPIMs was found not to be significant due to water occupying the micropores. Water/ion transport channels are developed from the intrinsic micropores in QPIMs, accompanied with expansion of the channel size by swelling. The QPIMs exhibited water permeability two times higher than that of the comparative dense QPPO AEM, measured by dynamic water vapor sorption. Although having a high IEC of ~2.1 mmol/g and high water uptake of ~ 70 wt%, QPIMs did not display a sudden increase in dimensional swelling in the application temperature range of 60-80 °C as QPPO did, which is probably due to the highly rigid polymer chain. QPIMs exhibited higher ion conductivities than those of QPPO with similar IECs. The lower energy of activation (Ea) and higher effective ion mobility of QPIMs indicated higher efficiency of ion conduction as a result of better interconnectivity of water/ion channels in membranes..

Keywords: Polymers of intrinsic microporosity; Anion exchange membrane; Ion transport channel; Water uptake; Fuel cell.

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NEURAL NETWORK MODELLING OF TOYOTA MIRAI PROTON EXCHANGE MEMBRANE FUEL CELLS USING PRINCIPAL COMPONENT ANALYSIS

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ABSTRACT

High-fidelity physics-based models can represent complex systems with high accuracy but can be too computationally intensive for real-time applications. Data-driven models such as neural networks (NNs) can yield competitive accuracy with reduced computation cost, may capture system-specific phenomena neglected in nominal physics-based models, and can be accelerated using parallel computing.

In this work, an ensemble of feedforward NNs is used to approximate pseudo-steady state operation of a hydrogen-based proton exchange membrane (PEM) fuel cell of a typical design used in production light-duty fuel cell vehicles. Training data is provided from simulations of a 2-D model fitted to experimental data from first-generation Toyota Mirai fuel cells. The baseline NN models achieve mean relative error of <6.6% versus ground truth data over 52 predicted output features corresponding to key operating conditions, as well as current density and water distributions.

The models are further optimized for computation speed by pre-conditioning the NN training data using principal component analysis (PCA), maximizing the variance per input feature and allowing for reduction of the input dimension by discarding negligible components. The models are then deployed on embedded hardware representative of typical automotive control systems, and evaluated on execution time and memory usage.

The PCA-reduced models achieve an overall reduction of 6-45% in neuron count compared to the baseline models, corresponding to memory reductions of 6-45% in calibration ROM and 8-40% in stack RAM. Aggregate execution time of the ensemble was measured at 146 μs and 107 μs on representative automotive controller hardware for the baseline and PCA-reduced models, respectively, representing a 26.7% reduction. For this improvement in performance (reduction in model size), the PCA-reduced models achieve mean relative error per output variable of 0.3-7.1% versus ground truth data, with absolute differences in mean relative error over the data set, per variable, of between -1.1% to +1.5% versus the baseline models.

In summary, PCA-reduced NN models of PEM fuel cells can achieve high accuracy in comparison with regular NN models and physics-based models at the computational speeds required for real-time embedded controllers.

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MODELLING THE IONOMER MORPHOLOGY IN HIGHLY POROUS CARBON SUPPORTS

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ABSTRACT

On the way to optimizing fuel cell performance and cost, it is vital to design the cathode catalyst layer such that a large triple phase boundary between the catalyst, ionomer and pore space and hence maximum catalyst utilization can be obtained. In this context, highly porous carbon supports have come to play an important role as their composition of carbon primary particles with internal nanopores strongly increases the surface area on which catalyst particles can be dispersed. However, the ionomer distribution on these supports is still a matter of discussion, with some authors stating that catalyst particles inside nanopores are not contacted by ionomer while others provide evidence that the ionomer does penetrate the nanopores to a certain extent.

In an effort to link literature findings and provide a more conclusive picture, we propose a simple, yet powerful model to simulate ionomer distribution and catalyst utilization depending on the ionomer content and different support types from low to high surface area. Input parameters for the model can be obtained from ex-situ experiments and include the primary particle geometry and pore size distribution of the support, particle size distributions for catalyst particles located within the support nanopores and on the outer surface of the support primary particles, respectively, and applied ionomer content. Concurrent with recent publications [1, 2], ionomer coverage is modeled to set out on the outer support surface for low ionomer contents, proceeding to increasing impregnation of sufficiently large pores for intermediate values and, for high ionomer content, blocking pore entrances with subsequent loss of catalyst/ionomer interface within the nanopores and a pronounced decrease in accessible pore volume.

The model allows for the calculation of a variety of parameters which can be checked against measurements, for instance, the accessible pore volume and specific surface area of the support before and after loading with ionomer and the percental ionomer coverage on the support and catalyst particles. Further, it provides information on hard to assess quantities such as the partition of the ionomer deposited inside the nanopores and the ionomer film thickness. Extensive validation against literature data shows good qualitative and quantitative correspondence and suggests the model as a versatile theoretical framework to explain and predict ionomer morphology on various carbon supports.

As an outlook for further application of the model, we propose that, due its mathematically simple approach, the model is straightforward to be incorporated into existing performance or degradation models. As a submodel, it can translate manufacturing parameters such as ionomer content and support type into morphological input information for these models and hence allow them to account in more detail for the effects porous carbon supports.

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Keywords: ionomer, high surface area support, modelling.

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SUPERHYDROPHOBIC FLUORINATED CARBONS FOR THE MICRO-POROUS LAYER OF POLYMER ELECTROLYTE FUEL CELLS

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ABSTRACT

Polymer electrolyte fuel cell systems (PEFCs) running on hydrogen are one of the most promising clean energy conversion technologies for a carbon-neutral society. Gas diffusion layers (GDLs) are employed at both electrodes to transport reaction gases and remove the products. At the cathode side of the PEFC, under the high current density operation, excessive water accumulation inside of the gas diffusion media hinders the transportation of oxygen to the catalyst layer. This phenomenon decreases the PEFC performance significantly. To overcome this, GDLs are usually coated with a hydrophobic microporous layer (MPL) comprising carbon black and a polytetrafluoroethylene (PTFE) binder. However, the use of PTFE can negatively impact the conductivity and gas diffusion properties of the MPL. In this study, we synthesize superhydrophobic fluorinated carbon (SHFC) as an alternative MPL material with a view to improving the water-repelling properties of the MPL.

SHCF powder was synthesized by reacting fluorinated alcohol with sodium at elevated temperature and pressure, and characterized via various techniques. Scanning electron microscopy (SEM) and transmission electron microscopy (TEM) images revealed the morphology of the SHFC to be a porous carbon with spheroidal nanostructures and regions with a high degree of graphitization. The water contact angle was measured to be 168°, confirming the superhydrophobic nature of the material. Thermogravimetric analysis (TGA) revealed high thermal stability of the SHFC up to 500 °C under nitrogen and air, indicating that the material will be stable under fuel cell operating conditions.

X-ray photoelectron spectroscopy (XPS) revealed an atomic concentration of ~90 at% carbon, ~8.8 at% fluorine, and ~1 at% oxygen with trace amounts of sodium contamination. XPS results also indicated that fluorine atoms are mainly covalently bonded (i.e. C-F bonds). Energy dispersive X-ray analysis (EDX) revealed lower fluorine content (2 at%) compared to XPS, suggesting that fluorination is concentrated near the surface of the particles. X-ray diffraction (XRD) showed that SHFC is largely amorphous. From the XRD, EDX and TEM results, it is concluded that small amounts of sodium fluoride are trapped in the porous structure of the SHFC which are not removed by extensive washing in water and ethanol.

The synthesized SHFC powder was then coated onto a GDL substrate and employed as an MPL material, using PTFE as a binder. Its performance was evaluated and compared with conventional carbon black-based MPLs. Single fuel cell performance tests were conducted under various high relative humidity conditions (>95%). Compared to the carbon black, SHFC-based MPLs showed higher performance in the high current density region, suggesting improved water management due to the hydrophobic nature of the MPL material. Constant loading tests at 1 A cm^{-2} confirmed the superior performance. This study was partially supported by NEDO (Contract No. JPNP20003).

Keywords: PEFC, water management, microporous layer, super hydrophobicity, wettability, fluorinated carbon

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EXPERIMENTAL STUDY ON THE EFFECT OF PURGING CONDITIONS ON PEMFC COLD START PERFORMANCE

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ABSTRACT

The proton exchange membrane fuel cell (PEMFC) starts up difficultly in subzero temperature environments is one of the main obstacles to its commercialization, and the membrane water content in PEMFCs before cold start is one of the key factors affecting its cold start performance. In this paper, PEMFC cold start experiments were carried out at different purging conditions to explore the influence of contact pressure, purging gas flow rate, and purging time on the cold start performance. The results show that for dry gas purging, the running time at 1 N•m assembling bolts torque is longer than that at 4 N•m, because the former contact pressure is smaller than latter, indicating excessive contact pressure is not conducive to cold start. At the fixed purging flow rate, the running time is first increased and then decreased with increasing purging time, showing a maximum value at 15 min. At the fixed purging time, the running time is first increased and then decreased with increasing purging flow rate, showing a maximum value at 1500 mL/min. Purging with humidified gas is beneficial to control the initial water content before cold start.

Keywords: PEMFCs, purging, cold start, contact pressure.

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NUMERICAL INVESTIGATION OF IMPACT OF ORIENTATİON ON WATER TRANSPORT IN PEMFC SERPENTİNE FLOW CHANNELS

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Abstract

It has been widely known that water management is one of the biggest challenges in Polymer Electrolyte Membrane Fuel Cells (PEMFCs). Flooding prevents oxygen molecules reaching the reactions sites. For inhibiting water flooding, different flow channels have been innovated. Among them the serpentine flow channel stands out with a rather good performance at the cost of high pressure drop. It is a fact that the bigger the pressure drop, the greater the power consumed by the fan. Analysis of flow channels in terms of water transport is crucial for minimizing the pressure drop and improving the cell performance. Computational Fluid Dynamics (CFD) models using volume of fluid method are useful for simulating two-phase flow in PEMFCs. A number of papers modeled two-phase flows; yet, they usually overlooked the impact of orientation which is an effective factor according to the experimental studies. Some of the papers investigated the effect of orientation on the water transport. However, these studies remained rather fundamental and they were conducted under impractical conditions. They analyzed the motion of a single water droplet coming out of a pore on the Gas Diffusion Layer (GDL). Water transport along the channel and the flooding phenomenon was not investigated. It was proposed that multiple pores must be defined along the channel for simulating the real water transport process. A paper studied water transport by multiple pores; however, they executed the calculations under impractical conditions. The current density was 0.8 A/cm^2 even though water flooding usually occurs at higher current density (around 1.6 A/cm^2). In addition, they carried out the calculations at relatively low air velocity (6.6 m/s). Numerical analysis of the water transport under different orientations and realistic conditions is demanded. This paper studies the impact of orientation on the water transport performance of a U-section of a serpentine flow channel under realistic conditions. A number of pores were modeled on the GDL for approximating the real water transport to the flow channels. Analyses were carried out for an air velocity of 10 m/s and current density of 1.6 A/cm^2. Water transport performance of the channel was investigated for three different orientations where two vertical and one horizontal cases inspected. Regardless of the orientation of the channel, most water accumulation is observed around the U-turn. When the air flow is perpendicular to the gravitational force, water accumulates in the U-turn. In the case where air enters the channel in the direction of the gravity, most water accumulation appears in the outlet section of the channel. Nonetheless, the best water transport performance is observed with this orientation. When the vertical orientations are compared, more water accumulation is noted before the U-turn in the case where air enters the channel in the opposite direction of the gravity.

Keywords: PEMFC, CFD, Two-Phase Flow, Water Transport, Orientation

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UNDERSTANDING STRCTURE-TRANSPORT RELATIONSHIP OF ION CONDUCTING POLYMERS

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ABSTRACT

Polymers functionalized with high concentrations of fixed ionic charges are critical components of solid-state electrochemical systems such as fuel cells. These ion-containing polymers play a key role not only as an ion-exchange membrane but also as nanometer-thick electrolyte “thin-films” within porous catalyst layer structures, where they bind the catalytic particles and provide transport pathways for the ions and reactant species. New generations of solid polymer electrolytes are being developed that push the limits of ion conductivity and durability. However, design parameters that connect the morphology and structure to polymer transport properties are still not completely known.

This presentation focuses on the understanding of the structure-transport interplay of various ion-conducting polymers and provides insights into the mechanisms that control their transport properties such as ion conductivity and water permeability. Critical designing parameters for next-generation polymers with better functionality will be provided. Topics such as newly developed polymer thin-film coating on various metal substrates towards use in platinum-free fuel cells will be covered.

Keywords: Ion-conducting polymers, fuel cells, structure-transport relationship.

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OPTIMIZING HYBRID BATTERY AND HYDROGEN ENERGY STORAGE FOR A RENEWABLE MICROGRID

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ABSTRACT

Microgrids — i.e., localized power systems that cover the generation, distribution, and consumption of energy — can be powered by distributed renewable energy resources, such as wind and solar to decrease the dependence on fossil fuels. In order to guarantee reliable electricity supply given high shares of variable renewable energy resources, microgrids rely on energy storage systems to bridge short, medium, and long-term mismatches between load and demand. Hybrid lithium-ion batteries and electrolytic hydrogen conversion and storage systems are capable of storing energy across these timescales and optimizing the sizes of renewable energy production and storage systems is key to ensuring that renewable-powered microgrids are economic and reliable. In this paper, we developed a linear programming method that optimizes hybrid battery-hydrogen storage in a wind-powered microgrid by minimizing the overall system cost and returns the component sizes and hourly energy flows. This method contributes to the existing body of work on microgrid energy storage by providing high-resolution (hourly) optimization over an extended timeframe (one year). A base case was simulated using the hourly weather and residential electricity load data near Toronto as inputs. Preliminary results show that in the optimal configuration, the hydrogen system has 1.5 times more power capacity than the battery system and 323 times more energy storage capacity, with the hydrogen system accounting for major seasonal variation and the battery cycling frequently. Hydrogen accounted for long-term seasonal storage and operated for 6657 hours in the year, whereas lithium covered shorter duration fluctuations and operated for 3736 hours.

An open-source python module will be released, which will allow users to input their own weather/energy production and load data and to specify key technological properties of their system, including component costs, efficiency, and minimum state of charge of the batteries.

Keywords: Microgrids, hydrogen, lithium-ion, energy storage, hybrid storage

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UNDERSTANDING THE ORIGIN OF THE LARGE ONSET OVERPOTENTIAL FOR OXYGEN REDUCTION ON PT(111) IN ACIDIC MEDIUM BY SOLVATION AND REACTION DYNAMICS

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ABSTRACT

The slow rate of oxygen reduction reaction (ORR) has been a fundamental challenge in the development of efficient fuel cell technology, and the mechanism of ORR on Pt(111) is a well-known model problem in electrocatalysis. Yet despite much efforts, the origin of the large ORR onset overpotential on Pt remains elusive, based on energetic calculations and kinetic modeling.

My group has recently taken a dynamic approach to address this problem from first principles in both acid and alkaline media [1, 2]. Our computational models take full account of the important factors in such a complex electrochemical process, not only with a Pt(111) slab for the electrode surface, but also with explicitly hydrated ions (H+, OH−, or metal cations), dynamic sampling of reaction channels at room temperature, and the variation in the electrode potential.

Our simulations show that the hydrogenation of an adsorbed O* atom to an adsorbed OH* is the key to understand ORR on Pt(111). It's well known that in acidic medium, there are two competing channels for O* hydrogenation: the required proton is supplied either from the solution (the protonation channel), or from an adsorbed H2O* (the hydrolysis channel). What has been missed by previous studies is the high sensitivity of the branching ration between O* protonation and hydrolysis with a varying electrode potential. At low electrode potential (modeled by a negatively charged slab), O* protonation dominates, while at high electrode potential (modeled by a positively charged slab), O* hydrolysis could be 100%. The dramatic swing is not due to the change in reaction energy or activation barrier, but due to the dynamics of H2O adsorption and its acid dissociation.

Such a swing not only explains the large onset overpotential for ORR on Pt(111), but also leaves fingerprints in other experiments, notably the irreversible feature in the oxide region of its cyclic voltammogram and the shape of its polarization curve near 1 V, both of which have also been long standing puzzles. Our results and analysis thus offer a consistent explanation for all these electrochemical measurements and point to new ways to improve the efficiency of ORR. It can be further extended to ORR on Pt(111) in alkaline medium.

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Keywords: fuel cell, oxygen reduction reaction, overpotential, reaction dynamics, first principles calculations

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AN EXPERIMENTAL ASSESSMENT OF PERFORMANCE, EMISSION AND COMBUSTION OF DTSI HIGH SPEED ENGINE FUELED WITH GASOLINE, CNG AND HYDROGEN

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HIGHLIGHTS

- The maximum power is developed with gasoline than CNG & hydrogen fuel.
- The maximum BTE (Brake Thermal Efficiency) is with hydrogen fuel, followed by CNG and gasoline.
- The minimum BSFC (Brake Specific Fuel Consumption) recorded with hydrogen fuel,
- The maximum volumetric efficiency drops observed with hydrogen fuel by 34 %.
- Hydrogen fuel did not emit CO and THC emissions. NO emissions reduced by 56.6 % over the gasoline.
- The maximum cylinder pressure recorded with hydrogen fuel 14 % more than gasoline at 10000 rpm.

ABSTRACT-

This experimental study[1] was conducted with electronically fuel injected single cylinder multivalve, high speed gasoline engine. Modifications were made on this engine to run on gaseous fuels such as CNG and Hydrogen. These gaseous fuels were injected with the help of electronic port fuel injection system. Combustion pressure sensor, wide band lambda sensor (LSU 4.9), gas injectors were the additional components added to this engine, for better fuel flow control and data acquisition. Wide Open Throttle (WOT) performances were taken with gasoline, CNG and hydrogen. Further in this study gasoline performance was considered as the baseline performance and will be compared with CNG and hydrogen performances. WOT performance with gasoline CNG and hydrogen were conducted from 3000 to 10000 rpm interval of 1000 rpm. From the results, the maximum brake thermal efficiency achieved is 39.5% with hydrogen fuel, this is an 8.5% improvement over gasoline and 3.9% improvement over CNG. Peak combustion pressure was observed to be 67.92 bar with hydrogen fuel, which is 14% more than gasoline fuel. When compared with gasoline fuel net heat release rate is reduced by 24% with CNG and increased by 30% with hydrogen fuel. Hydrogen has a maximum heat release rate since it has higher flame speed. The rate of pressure rise with hydrogen fuel is 1.6 times higher than gasoline fuel. NO emissions of hydrogen fuel were 57% less than gasoline fuel. From this experiment, it can be concluded that the existing spark ignition engine can be easily converted to hydrogen port fuel injection system with few modifications to meet the future stringent emission norms.

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DRE MOTORS - ADOPTION OF HYDROGEN TECHNOLOGY IN INDIA

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ABSTRACT

DRE Motors, is a startup, focused on the development of Green mobility solutions, and on building Hydrogen generation and distribution infrastructure. Our primary objective is to develop an advanced Hydrogen Fuel Cell System (HFCS) with improved performance efficiency, significantly lower costs towards achieving wider affordability of carbon-free mobility solutions. Adoption of such Green Mobility solutions will be limited by availability of Hydrogen and Refueling stations, towards which DRE Motors took up the challenge of developing high performance and highly reliable Hydrogen Electrolyser.

DRE Motors is working on offering HFCS and Electrolyser systems at very aggressive pricing of $350/kW, with an average efficiency of 60% & 65% respectively, and extended life time, thereby bringing Hydrogen mobility solutions into mainstream, directly pitching against ICE and BEV solutions.

DRE Motors designed & developed Hydrogen Fuel Cell System (HFCS) with patent pending Metallic Bipolar Plates, custom manufactured MEA thin membrane and optimal GDL - targeting light and medium duty commercial vehicles. DRE Motors team developed highly scalable Electrolyser technology with one of the best possible efficiencies and up time. While HFCS has been successfully tested and retrofitted into a 4X4 axle bus and a light duty commercial vehicle, progress on Electrolyser has been steady and we will be announcing product availability soon. Concurrently, we also offer aviation grade fuel cell in early stages of deployment. Our breakthrough products, have piqued interests among many stake holders with whom we are in the process of finalizing the deployment of DRE Fuel cell and Electrolyser in the market.

Keywords: carbon free, green hydrogen, fuel cell, electrolyser

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ELECTRIC TAXIING WITH FUEL CELL HYBRID POWER UNIT AND ITS ENVIRONMENTAL IMPACT AT AIRPORTS

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ABSTRACT

Airport ground operations have a great impact on the environment. Various innovative solutions have been produced so that aircraft can perform taxi movements by deactivating their main engines. Although they are quite environmentally beneficial, on board and external electric taxiing solutions that are actively used and planned to be used in airports are not completely carbon-free. Both types of systems have advantages and disadvantages in terms of meeting the energy needed for taxiing. The disadvantages of existing solutions can be reduced by using an external fuel cell hybrid power unit to meet the energy required for taxiing that does not put additional weight on the aircraft. An external fuel cell and battery hybrid power unit is proposed, which will be disconnected from the aircraft just before takeoff. To reveal the power and energy required by the system, the Airbus A320-200, which is a narrow-body aircraft and frequently used in airports, is considered. In order to determine the physical requirements of the aircraft for taxiing, a total of 900 seconds taxi-out movement consisting of four different periods with different runway slope, headwind and maximum speeds was examined. According to the determined physical requirements, the conceptual design of the proposed fuel cell battery system was created and the physical data of the system for each period were obtained in the Matlab Simulink environment. In addition, the amount of fuel consumed by the Airbus A320-200 for the determined taxi exit movement has been calculated and it has been investigated how much CO_2 and other polluting gases can be avoided in the case of the use of a fuel cell battery hybrid system, which is almost the size of a semi-automobile. Briefly, this external fuel cell hybrid power unit, which will travel around airports and connect to the needed aircraft, will provide the necessary energy for the ground movements of the aircraft results in cleaner and quieter airport operations as well as other operational advantages.

Keywords: Aviation, electric taxiing systems, fuel cell hybrid power unit, environment, simulink.

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PEM FUEL CELLS CATALYST LAYER RECONSTRUCTION AND MORPHOLOGICAL DETERIORATION UNDER HYGROTHERMAL CYCLES

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ABSTRACT

Durability is one of the main obstacles that inhibit the commercialization of polymer electrolyte membrane (PEM) fuel cells for transport applications, in which the microstructure of catalyst layers (CL) under dynamic loading conditions can be deteriorated under a long-term operation. In this study, CL's naturally random porous medium has been stochastically reconstructed to be a three-phase microstructure consisting of ionomers, catalyst agglomerates and pores, and morphological deterioration of reconstructed CL under cyclic hygrothermal stress has been investigated. The proposed reconstruction method extracts the two-point correlation function and lineal path function from experimental images. It turns the reconstruction problem into an optimization problem by minimizing the difference between the experimental images and the reconstructed structure. Subsequently, the Finite Element Method (FEM) is used to numerically investigate CL microstructure morphological changes under cyclic loading conditions. Two major observation includes ionomer coverage loss due to delamination between the thin ionomer layer and the catalyst agglomerate, and the ionomer residual volume accumulation. It is found out that the amplitude of hygrothermal cycles is the dominating factor in both delamination onset and the ionomer residual volume accumulation. More frequent start-up/shutdown of PEM fuel cells slows down the ionomer volume residual volume accumulation and the ionomer coverage loss. Longer parking time in the driving cycles alleviates the ionomer volume accumulation.

Keywords: PEM Fuel Cells; Catalyst Layers; Microstructure Reconstruction; Durability; Delamination.

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MECHANISTIC AND EXPERIMENTAL STUDY OF THE FORMATION OF BIOFUNCTIONALIZED NANOFIBER HYBRID MEMBRANE WITH ENHANCED PROTON CONDUCTIVITY

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ABSTRACT

Proton-conducting nanofiber hybrid membranes (PC-NFHMs) as promising candidates, are widely used for proton exchange membranes (PEMs) by constructing consecutive and long-range proton-conducting channels. Combing the properties and synergism from interactions between nanofibers and polymer matrix, the PC-NFHMs possess superior characteristics compared to individual ion-conducting polymeric membranes or free-standing electrolyte inorganic films. Herein, inspired by the structure of amino acid residues chain in transmembrane proteins, we propose two promising strategies for constructing amino acid clusters as a high-efficiency proton-conducting channel via immobilizing amino acid monomer onto the surface of nanofibers or spinning amino acid polymer into nanofibers. The prepared PC-NFHMs show competitive proton conductivity and low fuel permeability as well as single-cell performance for proton exchange methanol fuel cells (PEMFCs). Some deep insights into proton-conducting mechanisms (Vehicle and Grotthuss mechanisms) are explored by utilizing characterization methods including high-angle annular dark-field scanning transmission electron microscopy (HAADF-STEM) and small angle X-ray scattering (SAXS). Furthermore, structure–property relationships are proved through density functional theory (DFT) calculations. The calculated results of diffusion coefficients and mean square displacement of hydronium ions are well in good agreement with the experiments. These systematic discussions and proposed directions can trigger thoughts and provide ways to reasonably design PC-NFHMs for PEMFCs in the near future.

Keywords: Proton exchange methanol fuel cells; Proton exchange membrane; Proton-conducting channel; Amino acid clusters; DFT calculations.

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CHAIN CONFORMATION-DEPENDENT ION CONDUCTIVITY OF PEM: A MOLECULAR DYNAMICS STUDY

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ABSTRACT

Polymer electrolyte membrane (PEM) is one of the core components for polymer electrolyte membrane fuel cells (PEMFCs). Its microstructure influences ion and water transport significantly, which depends on the chain conformation. Poly(phenylene oxide) (PPO) based materials might be alternative promising candidates for polymer electrolytes. In this work, we conduct oriented arrangement of polymer chain structure and analyze the physical properties such as interaction energy, fluidity and free volume of polymer chains. It is found that the ordered arrangement of polymer chains significantly promotes ionic conduction. We study the ion conductivity of PPO-based polymer electrolyte by molecular dynamics simulation. Interestingly, by enhancing the structure orderliness, the ion conductivity of crystalline PEM is obtained as high as 0.085 S cm^{-1} at room temperature and 0.347 S cm^{-1} at 350 K, which are 1.5 and 4 times higher than the value 0.058 S cm^{-1} of corresponding amorphous polymer electrolyte. Our study provides useful information about the fundamental mechanisms that govern the ion conductivity of PPO-based PEM, which can be used for further optimization of high-performance PEMFC.

Keywords: Polymer electrolyte, ion conductivity, morphology, molecular dynamics simulation.

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PROTON CONDUCTING COVALENT ORGANIC FRAMEWORK MEMBRANES FOR HYDROGEN FUEL CELL

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ABSTRACT

Conventional polymer proton conducting membranes often suffer from significantly reduced conductivity under low relative humidity in fuel cell application. Covalent organic frameworks (COF) with pre-designable and well-defined structures hold promise to cope with this issue. However, fabricating defect-free, robust COF membranes proves an extremely difficult task due to the poor processability of COF materials. Herein, a bottom-up approach is developed to synthesize intrinsic proton-conducting ionic COF nanosheets in aqueous solutions via diffusion and solvent co-mediated modulation, enabling a controlled nucleation and in-plane-dominated growth. These nanosheets allow the facile fabrication of COF membranes with crystalline, rigid ion nanochannels via vacuum-assisted assembly method. The resulting membranes exhibit a weakly humidity-dependent conductivity over a wide range of humidity (30–98%) and a prominent fuel cell performance of 0.93 W cm^{-2} at 35% RH and 80 °C arising from their superior water retention capability and efficient proton conduction.

Keywords: proton conducting membranes, covalent organic framework membranes, hydrogen fuel cell.

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POLYMER ELECTROLYTE MEMBRANE WITH CORE-SHELL TIN PYROPHOSPHATE PROTON CONDUCTOR FOR FUEL CELLS ABOVE 200 ℃

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ABSTRACT

High Temperature Proton Exchange Membrane Fuel Cell (HT-PEMFC) has attracted extensive attention due to fast kinetics of electrochemical reactions, excellent CO tolerance and simplified thermal and water management. Improving the operating temperature of HT-PEMFC above 200 °C can further improve the energy conversion efficiency and provide diversified fuel sources. Nevertheless, phosphoric acid that is the-state-of-the-art proton conductor for HT-PEMFC would evaporate and dehydrate at temperature above 180 °C, resulting in severe degradation on the proton conductivity of the electrolyte membrane and then the HT-PEMFC performance under operating temperature above 200 °C. In this work, highly durable core-shell SnP_2O_7 inorganic proton conductor with good proton conductivity and thermal stability at 200-300 °C has been fabricated via a low temperature synthesis approach between Sn precursor and orthophosphoric acid under temperature below 300 °C. It has been revealed that the threshold temperature for formation of the core-shell SnP_2O_7 is 200 °C. By increasing the sintering temperature or prolonging the reaction time, the thickness of amorphous layer increases, and the crystal structure are growing more and more perfect. In addition, the core-shell structure has three layers and contains the crystalline SnP_2O_7 inner core, amorphous SnP_2O_7 interlayer and pyrophosphoric acid gel outer-layer. The ex situ X-ray diffraction characterization indicates that $Sn(HPO_4)_2$ is a very important intermediate for the formation of the core-shell SnP_2O_7 with the assistant of phosphoric acid, although the presence of water inhibits the transformation. Moreover, the core-shell SnP_2O_7 shows high proton conductivity of 0.084 S cm^{-1} at 260 °C and excellent durability over 200 h at the same temperature. Besides, the core-shell SnP_2O_7 has been introduced into the polybenzimidazole matrix via a two-step heating treatment. The obtained composite film shows good thermal stability, mechanical properties, and a fuel cell based on it reaches the maximum peak power density 270 mW cm^{-2} under 220 °C. Overall, the core-shell SnP_2O_7 is a promising high temperature proton conductor to be used in HT-PEMFC with operating temperature above 200 °C.

Keywords: HT-PEMFC, PBI, Core-shell SnP_2O_7, Composite membrane.

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HIGH DENSITY SULFONATED CARBON NANO-ONIONS AS AN EFFICIENT PROTON CONDUCTOR FOR SYNTHESIS OF NANOCOMPOSITE MEMBRANES WITH ENHANCED WATER RETENTION AND DURABILITY

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ABSTRACT

Proton exchange membrane fuel cell (PEMFC) has drawn extensive interest because of its high energy density, high efficiency, and low emission of pollutants, which is regarded as a promising and environmental friendly chemical engineering technology for both portable and automobile applications. However, the problem remains unsolved in PEMFC applications that the increase in proton conductivity is usually caused poor physicochemical stability. Incorporating hydrophilic nanofiller into membrane has been proven to be a simple and effective strategy to enhance the performance of proton exchange membranes (PEMs). A novel, large specific surface area, high density sulfonated carbon nano-onions (SP-CNOs), is proposed as a nanofiller in sulfonated poly(arylene ether sulfone) (SPAES) to regulate the highly conductive proton transfer channels. The mesoporous SP-CNOs possess an average pore diameter of 9.7 nm and a large specific surface of 350 m^2/g, which impart to their good dispersivity and hydrophilicity. The electrostatic interactions between SP-CNOs and SPAES endow the composite membranes with good interfacial compatibility and enhanced mechanical toughness, thermal and oxidative stability. As a result, an enhanced water-retention environment and restricted swelling behavior have been formed. In the composite membranes, the low-energy-barrier proton transfer channels are constructed by the high density sulfonic acid groups presented in SP-CNOs, promoting proton conduction improvement. The proton conductivity of the SPAES/SP-CNOs-1.5 membrane achieves a highest value of 181.2 mS/cm at 90 °C; the H_2/O_2 fuel cell performance is recorded at a power density of 735 mW/cm^2 at 80 °C, which is slightly better than Nafion® 112. After an accelerated stress test, the used SPAES/SP-CNOs-1.5 membrane exhibits lower CV decay rate and better fuel cell performance than the used pristine SPAES membrane. On the basis of the results of the good physicochemical stability and electrochemical performance, we can infer that the composite membranes possess great potential in PEMFC applications.

Keywords: Sulfonated carbon nano-onions; Proton exchange membrane; Water-retention environment; Durability assessment; Fuel cell.

Abstracts of Poster Presentations

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GRAPHENE OXIDE COMPOSITE AND MULTILAYER MEMBRANES FOR INTERMEDIATE TEMPERATURE PEFCS

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Polymer electrolyte fuel cells (PEFCs) performance can be enhanced by operating them at elevated temperatures. Intermediate temperature fuel cells (up to 120℃) are targeted as the next generation of PEFCs. This increase in operating temperature results in faster reaction kinetics as well as a simpler cooling and water management systems. These improvements would have significant benefits in the use in automotive systems. Unfortunately, the increase in operating temperature causes a drying of the membrane and reduction in water to facilitate the transport of protons. The subsequent dehydration of the membrane leads to an increase in hydrogen crossover and the potential formation of pinholes. Subsequently, this can result in the formation of radicals that can attack the membrane and membrane electrode assembly (MEA), which can end in catastrophic degradation of the MEA.

Potential solutions include using alternative polymers to Nafion, those that are more thermally and mechanically resistant, such as sulphonated polymers (e.g. sulphonated poly (ether ether ketone), SPEEK). In this case, the challenge is increasing the proton conductivity to levels comparable to Nafion. Other alternative polymers include Aquivion, a short-side-chain (SSC) polymer similar to Nafion, but with increased thermal resistance [1]. Another resolution involves the design of composite membranes, where a filler material is interspersed throughout the polymer matrix. In this case, the properties of the filler are combined with those of the polymer. Many characteristics which can possibly improve performance include thermal, mechanical and oxidative resistance, hydrophilic and hygroscopic behavior and improved proton conduction [2]. Many filler materials have been researched for their use in either intermediate temperature fuel cells or those operating under dry conditions. Filler materials studied include carbon nanomaterials, metal oxides and ionic liquids.

Graphene oxide (GO) is a prevalent choice of filler material because of its hydrophilic properties as well as its mechanical strength [3]. These GO membranes, either as a polymer composite or a filtered pure GO membrane have shown to reduce hydrogen crossover as well as improve proton conductivity [4]. A potential drawback of a single composite membrane is the prevalence of non-uniformity and hence non-uniformity in this performance. Fortunately, a possible solution to this issue is the use of multilayer membranes, where there are multiple layers of different materials. This allows us to control the specific functions of each layer, without having a dispersion throughout a single layer composite membrane. Currently, the use of solution casting to fabricate multilayer membranes is under explored, with the majority of these multilayer membranes prepared via spraying or layer-by-layer assembly.

Here we report the fabrication and results of composite GO membranes and multilayer GO membranes. Both membranes have been prepared with the solution casting method. Their structure has been characterized with a variety of techniques and their performance was assessed as a MEA in a fuel cell. Preliminary results reveal better performance for the multilayer membrane in comparison with the composite. Moreover, both composite and multilayer GO membranes demonstrate smaller reduction in performance at elevated temperatures in comparison to recast nafion.

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Keywords: WFCC, membrane, intermediate temperature

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A CONSTITUTIVE MODEL FOR PREDICTING THE TIME AND TEMPERATURE-MOISTURE-DEPENDENT BEHAVIOR OF NAFION POLYMERS

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ABSTRACT

Proton exchange membrane fuel cell (PEMFC) is a kind of high-performance fuel cell which converting hydrogen energy to electrical energy. As the core components, the proton exchange membrane (PEM) determined the mechanical, and influence the performance of fuel cell. A newly developed constitutive model is developed for predicting the time and temperature-moisture-dependent mechanical behavior. The model is aiming at predict the stress response of PEM under different strain rate, temperature, and relative humidity. The stress–strain behavior of Nafion polymer is tested between 25°C to 80°C, and relative humidity between 30%~70% through uniaxial tension. Comparing the experiment data with the model prediction show that the constitutive theory captured the response, especially under different humidity and temperature.

Keywords: PEM, constitutive model, Nafion.

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Study on preparation and performance of membrane electron assembly in proton exchange membrane fuel cell

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ABSTRACT

The Membrane Electron Assembly (MEA) is one of the core component of Proton Exchange Membrane Fuel Cell (PEMFC), which affects the life cycle and performance of PEMFC. Exploring and optimizing various MEA preparation processes is a key factor to promote the commercialization of PEMFC. Here we describe three methods of preparing highly active MEA using commercial Pt/C and self-made PtCo/C catalysts, which is traditional method, ultrasonic spray method, sputtering deposition method. Besides, the microstructure of the catalyst layer in MEA was characterized among three methods. Finally, the catalyst loading and the I/C ratio of the slurry have also been studied, which are key factors affecting the performance of PEMFC.

Keywords: MEA, PEMFC, ultrasonicspray method, sputtering deposition method

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The addition of hydrophobic materials to enhance the mass transfer of Fe/N/C catalysts in membrane electrodes

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ABSTRACT

It is a challenge to replace platinum group metal(PGM) with non-noble metal catalyst for oxygen reduction reaction, which is significant for large-scale deployment of proton exchange membrane fuel cells (PEMFCs). Highly supported Fe/N/C catalysts have shown comparable performance to commercial Pt/C catalysts. However, the performance loss of the mass transfer zone caused by the thick catalyst layer makes it prone to water flooding and has poor durability. Here, we synthesized conventional Fe/N/C catalyst with the addition of hydrophobic vapor phase silica or PTFE nanoparticles. The influence of the amount of hydrophobic material on the mesoporous structure and hydrophobicity of the catalyst was investigated, so as to achieve the purpose of enhancing water conduction without affecting the performance of the catalyst itself. The results showed that when the addition of SiO2 or PTFE without catalytic activity was controlled, the catalyst activity would not be reduced, but the defects in the pyridine nitrogen and carbon matrix would be introduced and more active sites would be generated. At the same time, enhanced water conduction, reduced water flooding and mass transfer resistance.

Keywords: PEMFCs, non-noble metal catalyst, hydrophobic, mass transfer

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MESOPOROUS PLATINUM CATALYST ALLOYED WITH IRIDIUM AS A CORROSION-RESISTANT CATALYST FOR FUEL CELL

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ABSTRACT

Polymer electrolyte membrane fuel cell (PEMFC) has the advantages of high energy density, high efficiency and theoretically zero emission, and is expected to replace the internal combustion engine to solve the problems of environmental pollution and resource shortage. However, the low stability of catalysts has severely impeded the commercial application of fuel cell. Corrosion of carbon support is the main factor affecting the catalyst stability, which causes the detachment/agglomeration of Pt nanoparticles, and results in the severe decreases of the ECSA, attenuation of catalyst, performance loss, and lifetime decay of PEMFCs [1].

Here, mesoporous Pt-Ir alloy nanosheets were synthesized with the assistance of ordered arrangement of micelles and two-step reduction process. The unique porous structure and morphology were characterized by scanning electron microscopy (SEM) (Fig. 1a), which shows uniform mesopores structure with a diameter ca. 40 nm. This regular distributed mesoporous structure is considered to benefit higher surface area, provide abundant active sites and facilitate the transportation of reactants, leading to excellent electrochemical performance in fuel cell applications [2]. To mitigate carbon corrosion, iridium (Ir) is introduced to alloy platinum (Pt) as an additive, with the Pt-Ir ratio of 85:15, which is an efficient catalyst for the oxygen evolution reaction (OER). The elemental mapping results (Fig. 1b-c) reveals that Ir was successfully incorporated into Pt and uniformly distributed in it. The incorporation of Ir promotes the decomposition of water around the carbon supports and protects carbon support from electrochemical corrosion effectively. Supported on the carbon black, the Pt-Ir/C catalyst is obtained, which supposed to exhibited improved activity and stability compared with commercially available Pt/C. In future studies, electrochemical measurements and single cell tests will be carried out to further demonstrate the excellent performance and carbon corrosion resistance of prepared catalyst.

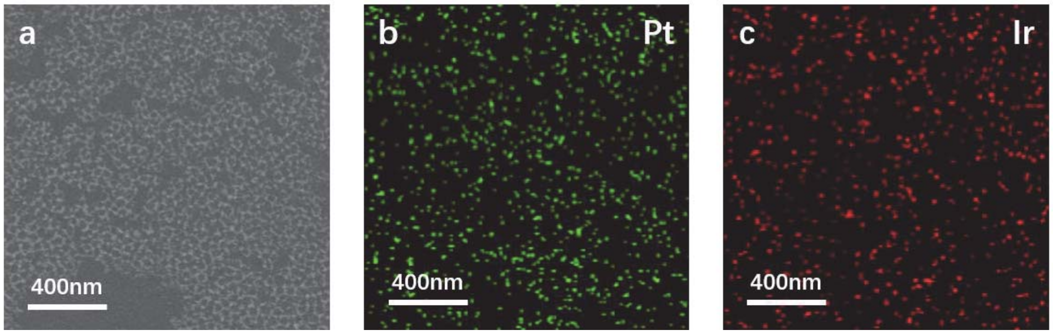

Fig. 1 The morphological (a) SEM images of mesoporous Pt-Ir nanosheets, and corresponding (b) Pt and (c) Ir element mapping images.

Keywords: carbon corrosion, stability, catalyst, fuel cell.

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MODELING THE WATER ELECTROLYSIS REACTION IN OVERLAPPING CATHODE/ANODE ELECTRIC DOUBLE LAYERS

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ABSTRACT

The electric double layers (EDLs) at cathode and anode are brought into overlap when the inter-electrode distance falls into the Debye length scale. The overlap structure dramatically changes the local reaction condition for water electrolysis, and is promising to achieve pure water electrolysis with both high-efficiency and low material cost [1].

In this talk, we present a mean-field model to study the water electrolysis reaction in overlapping cathode/anode EDLs. At first, we introduce the structure and characteristics of the overlapping cathode/anode EDLs. Then, we discuss the effects of the dissociation and orientation polarization of water on the structure of the overlapping cathode/anode EDLs. Moreover, the kinetics of water electrolysis reaction under the pH distribution are investigated. It is found that the overlapping cathode/anode EDLs greatly facilitate the water molecules ionization and mass transport, which greatly reduces the activation and ion transport losses.

This study will lay the foundation for the development of new water electrolysis technologies that are membraneless, need no added electrolytes, have high efficiency, and use low-cost materials.

Keywords: water electrolysis reaction, effects of overlapping electric double layers, water dissociation reaction.

Reference:

[1] Wang, Y., Narayanan, S. R., & Wu, W. ACS Nano, 2017, 11(8): 8421-8428.

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ELECTROCHEMICAL IMPEDANCE STUDY OF PROTON EXCHANGE MEMBRANE WATER ELECTROLYSIS

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ABSTRACT

Proton exchange membrane water electrolysis (PEMWE) is a candidate for the production of high purity hydrogen, compared with other kinds of water electrolysis, it has the advantages of high current density, high voltage efficiency, rapid system response and dynamic operation. Deep understanding of the reaction process and loss origin is beneficial for improving the performance and optimization design of PEMWE. In this regard, electrochemical impedance spectroscopy (EIS), as an in-situ characterization tool, is commonly used in distinguishing electrochemical processes and monitoring performance of PEMWE. Whereas, in literature, there is no unified interpretation for EIS of PEMWE cell, which is mainly due to the lack of the separation of individual electrode impedance and corresponding physical model rather than equivalent circuit model. Herein, we introduce a reference electrode to separate the impedance of cathode and anode and interpret them with reasonable physical models. At the same time, we establish the transformation relationship of polarization curve and EIS, and examining the effectiveness of reference electrode. Combing the experiments and model, we obtain quantitative description of different loss in PEMWE. Further, we give some effective suggestions for the design and optimization of the PEMWE cell.

Keywords: Proton exchange membrane; Water electrolysis; Electrochemical impedance model; Reference electrode

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Research on Porous Transport Layer in Proton Exchange Membrane Water Electrolysis

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ABSTRACT

The porous transport layer (PTL), as a key component of the proton exchange membrane water electrolysis (PEMWE), has an important influence on mass transport, electron conduction, and even electrochemical reactions. The mass transfer behavior of PTL in PEMWE is still unclear, and it is worthy of further study. However, the extra resistance caused by PTL and the influence on the electrochemical reaction have a greater impact on electrolytic performance. In this study, the PTL was tested ex-situ and in-situ to examine its effects on PEMWE. Respectively, the ex-situ experiments included the use of a pressure measuring membrane (PMF) to check the compression unevenness of the newly designed electrolytic cell, and the use of a cell without a membrane electrode assembly (MEA) to measure the PTL resistance. The in-situ experiment included the I-V curves of 8 combinations of PTLs and the potentiostatic electrochemical impedance spectroscopy (PEIS) of these PTLs at a cell voltage of 1.5 V. This work presents that the PMF uses a new flow channel configuration design to perform a complete analysis of the electrolytic cell, which shows that the pressure distribution in the cell is non-uniform. The compression of gas diffusion layer (GDL) is compressed much more heavily than PTL after assembly. The resistance of bulk PTL and PTL/bipolar plate (BP) interface resistance is negligible. It was also found in the in-situ experiment that the I-V performance has no hysteresis under the working conditions of 80 °C, the ambient pressure, and the water flow rate of 5 mL/min. The interface resistance of the PTL/catalyst layer (CL) is the main component of the entire high-frequency resistance (HFR). The interface resistance of the component PTL/CL will decrease with a higher component fastening force. The EIS results show that at the intermediate frequency, the basically similar circuit is attributed to the hydrogen release reaction (HER), while at the low frequency, with the increase of the current density, the radius of low-frequency circle gradually increases, which is attributed to the oxygen evolution reaction (OER). This study explored the influence of PTL on electrolysis performance. Combined with the analysis of experiments and simulations, it shows that the extra resistance caused by PTL and its influence on the electrochemical reaction.

Keywords: Porous transport layer (PTL), Proton Exchange Membrane Water Electrolysis (PEMWE), Electrical Resistance.

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FABRICATION OF THE ALIGNED NANOFIBERS FOR ELECTROSPUN CATALYST LAYERS

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ABSTRACT

Catalyst layer (CL) is the key component of fuel cell, facing the needs of low Pt loading, high performance and high durability. Fabricated with the electrospinning techniques, the electrospun CL could improve the fuel cell performance by increasing the electrochemical surface area, strengthening the water management and smoothing the mass transport [1][2]. The previous electrospun CLs usually presented a random nanofiber network and much focus have been put on the understanding of single nanofiber. The nanofiber morphology in the CL might not be paid enough attention, which is significant to the oxygen and water transport. Here we introduced a method to fabricate the aligned nanofibers for electrospun catalyst layer. The structure of the nanofibers was mainly regulated by controlled the electric field of collecting substrate and the space between the collecting substrate and the needle. The electric field of the collecting substrate were designed with two parallel smooth silicon wafers to control the fiber arrangement. The collecting substrate was directly used with Nafion membrane. The electrospinning ink was studied to enhance the electric field force for better nanofiber alignment. Parallel structure of the nanofibers was obtained, as shown in Fig 1. Electrochemical diagnostics including the polarization and the cyclic voltammetry were used to evaluate the performance of the CL with aligned nanofiber structure and the random nanofiber structure. Ex-situ methods including the SEM and BET were observed to characterize the nanofiber morphology and pore structure. High performance was found with the CL with aligned nanofiber structure.

Keywords: Fuel cell, electrospinning, nanofibers, aligned fiber

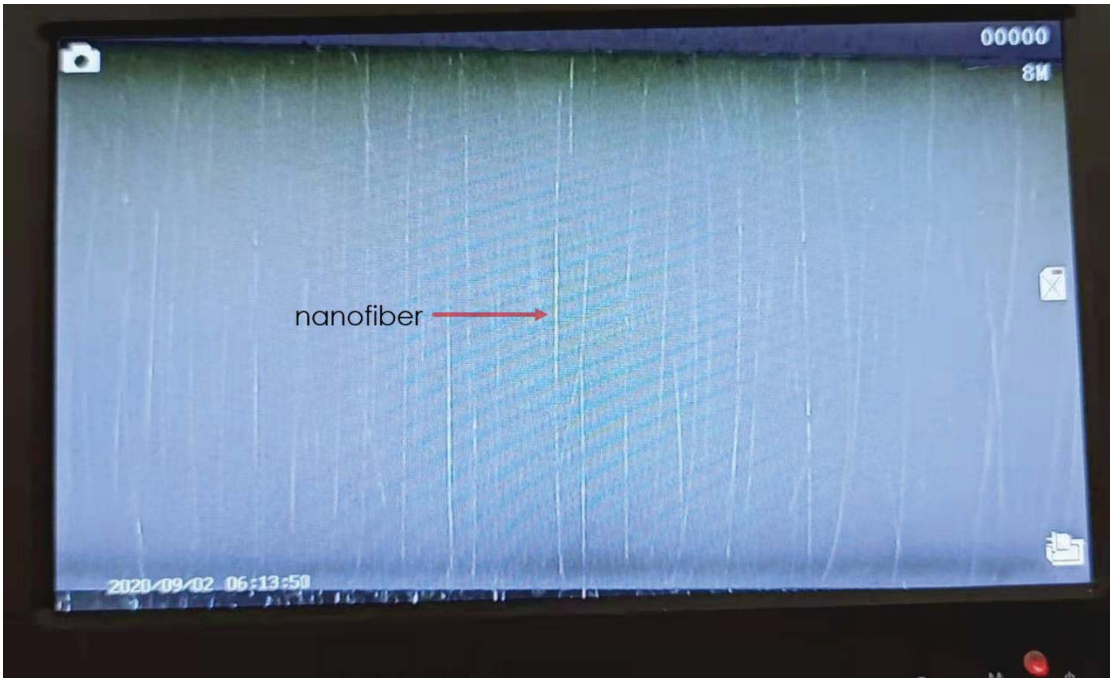

Fig 1 Parallel structure of the nanofibers with electrospinning (Voltage in needle :+9 kV; Flow rate :0.23ml/h; distance between the needle and the collecting substrate:9cm ;Temperature :26°C; Relative humidity :36%;)

Reference

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EFFECT OF STRUCTURE PROPERTIES OF CATALYST LAYER ON TIPPING WATER BALANCE IN POLYMER ELECTROLYTE FUEL CELLS

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ABSTRACT

Low Platinum loading is essential for breaking the commercialization bottleneck of proton exchange membrane fuel cell (PEMFC). Experimental studies have shown an unexpected voltage loss with the decrease of Pt loading. There are two causes for such a performance loss, one is the mass transport resistance of ionomer thin film covering Platinum surface in catalyst layer (CL) [1], and another is tipping water balance [2]. With the decrease of Pt loading, on the one hand, effective evaporation area of the CL decreases, on the other hand, the water production rate of per unit Pt area increases under same current density. These two effects lead to tipping water balance, resulting in the unexpected voltage loss. Such a phenomenon puts forward higher requirement on CL water management, which is influenced by CL structure and property. In this work, we explore the impact mechanism of CL structure on tipping water balance. In sample fabrication, CL with different Platinum loading, thickness and porosity were fabricated as shows. In order to eliminate the influence of local mass transport resistance, the I/C ratio of these CL is the same, and the local mass transport resistance is measured for verification. In cell design, commercial gas diffusion layer (GDL) is replaced with gold mesh to emphasize the mass transport resistance of CL. The structure, property and performance of CL with different structure are characterized and analyzed. And finally, based on understanding of the mechanism, we propose the optimal CL structure design direction for low Pt loading CL.

Keywords: fuel cell, catalyst layer, tipping water balance, structure property, structure design

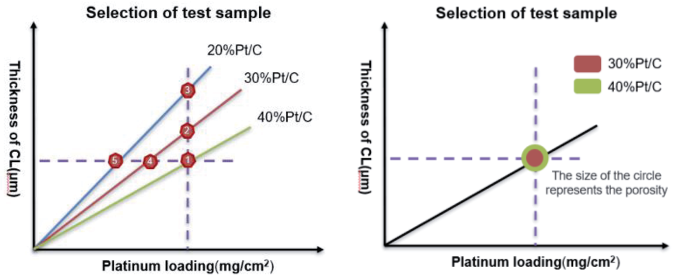

Figure 1 test sample

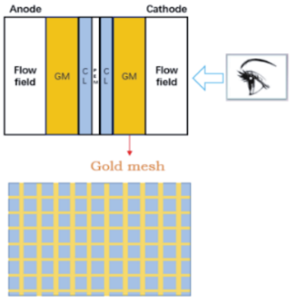

Figure 2 Replace the GDL with gold mesh to eliminate the effect of GDL

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REVIEW: STRUCTURE AND PERFORMANCE RELATIONSHIP OF CATALYST LAYER IN POLYMER ELECTROLYTE FUEL CELL

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ABSTRACT

Cost and durability are still two remaining challenges for the large-scale commercialization of polymer electrolyte fuel cell (PEFC). Increasing the power density is an effective way to reduce the cost of catalyst and other components. To date, researchers have presented many innovative ideas and achieved great progress in improving the performance of catalyst layer (CL). However, large gap still exists between targets and practical performance. In this paper, we review the latest state-of-art CL performance and focus on the structure-performance relationship from CL preparation process to formed CL structure, then to the final electrochemical performance. We reviewed the latest work of optimizing CL in a structure perspective. We analyzed the effect of controlled parameters in preparation process on the structure properties of CL. By introducing structure parameters in performance model of fuel cell, we discussed the structure-performance relationship.

State-of-art performance studies most focus on the change on material level and characterization of formed structure. Kamitaka et al. [2] changed the catalyst support's type to mesoporous carbon and improved pore structure. Ott et al. [3] tuned the carbon support characteristic to control ionomer distribution. Doo et al. [4] and Li et al. [5] avoid the direct contact between ionomer and catalyst by adding other substances.

The structure of CL consists of micro and macro structures. There are some design rules for the structure of CLs with optimal performance. For microstructure, optimal structure contains characteristics such as highly dispersed and narrow particle size distribution catalyst, uniform distributed ionomer, abundant proton conduction network, indirect-connected interface between catalyst and ionomer and sufficient micro-channels for mass transport, etc. For macrostructure, multi-modal distributed pores are expected for reaction and product transport.

Two parameters were introduced here to describe the CL structure. One is the degree of order, which indicates the quality of proton conduction and mass transport network. For example, template-based CL such as 3M company's ultrathin catalyst layers (UTCLs) have a high degree of order than the traditional ink-based CLs. While, degree of redundancy indicates ionomer relative content in the CL. Specific ionomer ratio reflects the balance level between proton conduction network and ease of gas transport. These two parameters connect the materials themselves and their interaction process with the final structure and performance.

Previously, some scholars began to study the intermediate process in the last decade, containing the interaction between materials in ink state and ink transition process during mix, deposition and dry steps [6]. Besides, via tuning the material and ink preparation process, a higher degree of order and lower degree of redundancy can be achieved at the same time [7]. Here, we extract the correlation of structural parameters between ink and formed CL structure and state-of-art PEFC performance. A simple model from ink state parameters, containing particle size distribution to the formed CL structural parameters, containing pore size distribution and proton conduction network and performance is conducted. The value of degree of order and redundancy of different CLs is evaluated and used as input into the performance model.

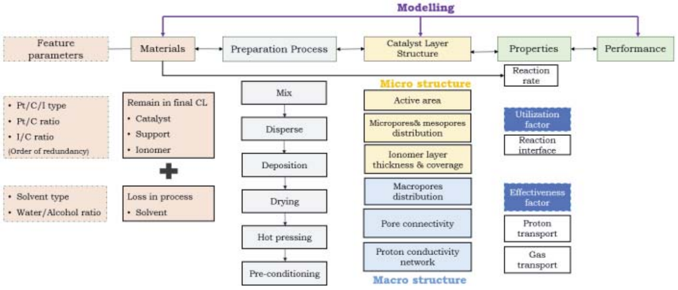

Fig 1. Structure-Performance Relationship

Keywords: Polymer electrolyte fuel cell, catalyst layer, optimal structure, structure formation process, structure-performance relationship

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